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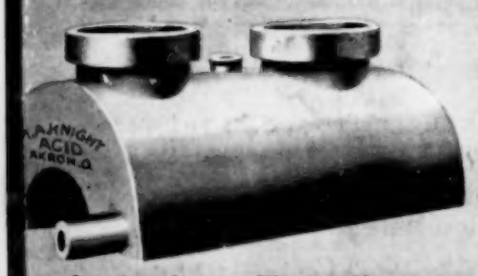

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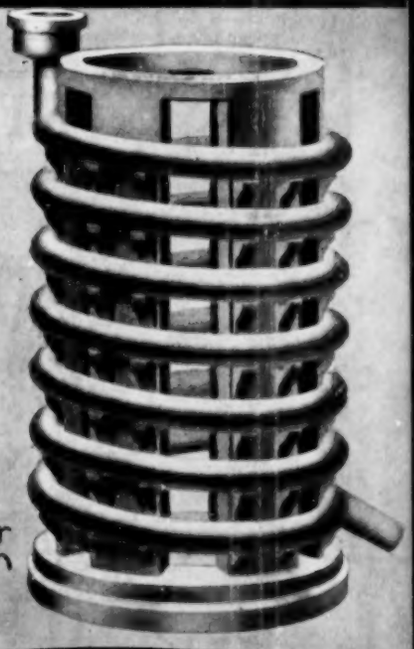
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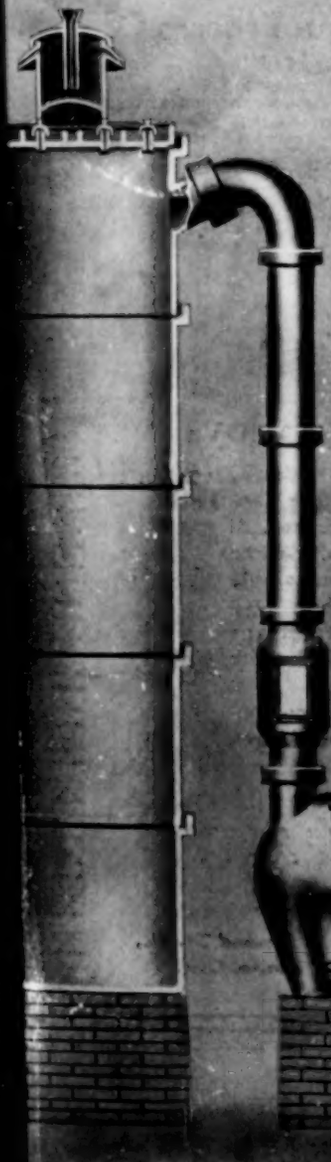

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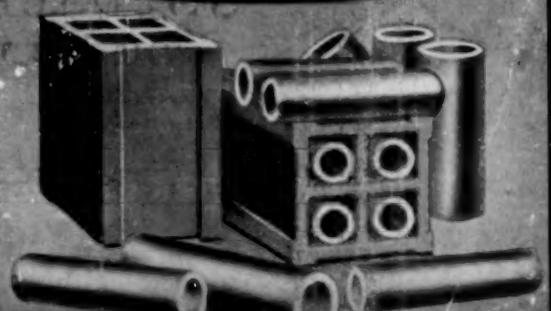

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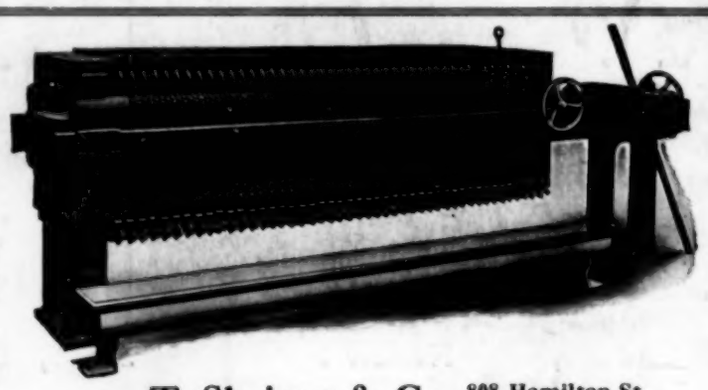

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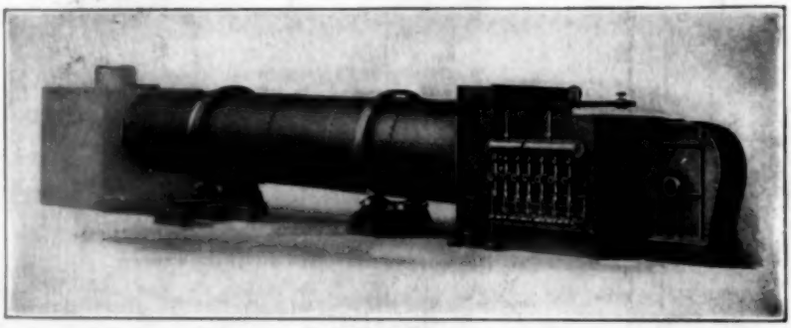

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## The Place Value of the Waterpowers of the Pacific Coast for Electrochemical Industries

In this issue we publish a very readable, enthusiastic and decidedly sensible paper by Mr. John Wood Beckman on electrochemical possibilities of the Pacific Coast states. This paper gives us a welcome opportunity to discuss in a few words the relative value of waterpowers in different localities. Waterpowers have been very much talked about recently. With what has been said about the urgent need of removing the unwise and directly foolish legal restrictions which hamper the development of American waterpowers at present in the most serious manner, we fully agree. But we are somewhat under the impression that the owners of waterpowers in different parts of the country, together with the commercial interests depending on them, have not always taken a scrupulously correct attitude toward each other. There have been some indications of jealousy or, shall we say, provincialism. It is perfectly natural that the owner of a waterpower thinks that his own waterpower is the most important. It certainly is for him. But we don't see the slightest justification for such jealousy as is natural between competitors in other lines. The reason is simply that as things are there can be very little competition between different waterpowers. The sphere of usefulness of a waterpower as potential producer of an electrochemical product can be accurately figured from the cost of power and of raw materials, operating cost, selling price and the very important item of freight charges from waterpower to market. Any waterpower has its own restricted market beyond which it cannot extend its usefulness economically, and it will be found that the market zones of the most important waterpowers overlap very little. All that is really needed in order to convince oneself of the truth of this statement is to tabulate the freight-rates from any one waterpower to the principal industrial centers of this country.

To give one concrete example which is rather extreme, we may refer once more to the present power famine in Niagara Falls. In order to find a remedy, it would be plain foolishness to think that the abundant and relatively cheap waterpowers of the Pacific Coast could be used as a substitute for Niagara power to supply the principal markets now supplied by the Niagara Falls electrochemical industries. The freight rates from the Pacific Coast to the manufacturing districts of the East and Middle West are prohibitive. Competition in this market between electrochemical products from Niagara power and from Pacific Coast power is therefore an economic impossibility. But has anyone ever seriously suggested this? Mr. Beckman's paper

is just one more proof that the Pacific Coast clearly understands the situation and looks out for its own market. But if there cannot be commercial competition why should there be not a real attitude of mutual helpfulness between the waterpower interests of the East and the West?

There is a very simple fundamental reason why freight rates are of such enormous importance in determining the selling zone of a waterpower as an electrochemical producer. It is a well-known fact that the usefulness of so many electrochemical products is due to the stored energy in them. In other words, that the sale of so many electrochemical products is a case of chemical power transmission. But chemical power transmission, unlike electrical power transmission, depends on ordinary transportation means—railroads, ships, etc.—and this fact makes freight rates all important in chemical power transmission. And this is even more so in this country than abroad. In our issue of March 15, 1916, in discussing the place value of waterpowers, we gave indisputable figures showing that while this country is easily the foremost industrial nation, in that it has succeeded in multiplying the natural working productiveness of its average citizen by industrial development, yet, on the other hand, this country is very much less industrially populated than England or Germany, and the cost of transportation between the different industrial centers among each other and between industrial centers and sources of raw materials and markets respectively is very much greater. This consideration explains why in the chemical industries certain things are possible in Germany which are impossible in this country. It also explains why Niagara's unique position among American waterpowers is, to a large extent, due to its connection to the Great Lakes, with 3600 miles of shore line and navigable to the very docks at Niagara. The least expensive sort of transportation is thus provided for Niagara products to markets representing nearly half the population of North America, while the least expensive supply of raw materials is provided in many cases by the same water way, quite aside from the railroads running from Niagara in all directions.

Now, what are the possibilities of electrochemical industries on the Pacific Coast? Mr. Beckman discusses this very question in an interesting way by basing his discussion on certain analogies between the conditions of the Pacific Coast and those of Sweden and Norway. Of course, the Pacific Coast States themselves offer at the start a ready market for electrochemical products, and this market will grow, but it is not large enough, nor will it be large enough for a long time to come in order to absorb all the products that could be made with the immense waterpowers available and waiting for development. Mr. Beckman is right: the Pacific Coast will have to follow the lead of Sweden and Norway and look for export trade and learn "the art of handling tramp steamers." "We can reach from the Pacific Coast over one-half of the world's population by going west and south. Some of the markets are small, but they are bound to grow, and if we miss the present opportunity somebody else will step in and collect the harvest which legitimately belongs to us."

Clearly, there are almost unlimited possibilities. But the amount of work that remains to be done to transform this vision into a reality is immense. Yet the pioneer spirit of the people of the Pacific Coast is just fitted for the task. When once the problem and the opportunities are realized; when, as Mr. Beckman puts it, an "electrochemical atmosphere" has been created, it may be safely left to the people of the Pacific Coast themselves to do the rest. The Pacific Coast has undoubtedly more potential wealth in its 11,000,000 hp. of waterpower, of which 93 per cent now goes to waste, than in all the gold that was ever mined or is still to be mined in those States. But an export trade must be created. The Golden Gate will then become the gate to a new and glorious future of the empire of the Pacific Coast.

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### Labor and Prosperity

The wages of men engaged in the production of the base metals are now quite generally based on the market price of metals, with a sliding scale that automatically adjusts wages to changes in the market. This arrangement has prevailed in the copper industry for several years, and has been adopted in some measure in the case of lead and zinc. Wages at the present time are accordingly much higher than before the war, due to the increased price of metals.

Assuming a fair and reasonable base wage and rate of increase, the idea is equitable and commends itself as a just means of insuring harmony and contentment. It appeals to the wage earner, particularly as long as prices rise and wages increase; but he takes a reverse situation with bad grace, even though it is still fair and equitable. Becoming accustomed to unusual prosperity, he seems to accept it as a standard condition and regards any unfavorable change as an encroachment on his established rights. He is not what is called a good loser, even though as a matter of fact he loses nothing except as the operator also loses. Labor may not be insincere in accepting sliding wage scales, but it shows moral incapacity when called upon to take reverses.

In the Joplin district wages for a certain class of labor were based at $3.50 per day when zinc concentrate sold between $50 and $60 per ton, with an increase of 25 cents per day for each increment of $10 in the average price of concentrate above the $60 limit. Several times the operators have paid a 25-cent increase when the average price of concentrate for a month exceeded one of the $10 limits by narrow margins of less than $1. Recently when the average price of concentrate fell below one of the limits by only $1.88, labor not only objected to the corresponding cut in wages, but demanded an increase of 25 cents per day over the current wage. Failing to get the increase, they threatened a strike.

Instances could be multiplied to show the unreasonableness of men after temporarily enjoying unusual advantages. It is a human trait and not a peculiar characteristic of prosperous labor, but it crops out in a most unfortunate way in the latter class and brings merited

condemnation. A little more reason, appreciation and sense of moral obligation would fortify labor's position in a marked degree.

## A Scientific Tariff for Steel?

It is a fortunate thing for the iron and steel industry that both political parties are committed to the principle of a tariff commission. Both now carry the idea as a platform plank, and the party in power is enacting a tariff commission bill into law.

One may rejoin that the mere expectation that some sort of a tariff commission, with unknown personnel, is to be established, is narrow ground on which to congratulate the steel industry, but things must be considered in their relation. There could be nothing worse than the tariffs the country has had, or the methods by which they were constructed, or the utter abandon with which they have been modified. The condition has been so bad that practically any step would be a step toward better things, if not a step in precisely the right direction.

A tariff commission should be able to produce, eventually, a scientific tariff. It would be able to proceed upon known facts, as it gathered the facts, but that is only one feature. Hitherto the tariff has been revised simply as political need or political opportunity presented itself, the facts as to the course of trade, the volume of our imports or the volume of our exports of a given commodity having nothing to do with the determination of the party controlling the Congress to revise the tariff.

One of the things a tariff commission would necessarily do would be to study the working of the existing tariff, observing what material it let in and what material it kept out, then endeavoring to determine whether the flow of material, or lack of flow, was for the best interests of the country. A conclusion that the condition as to the specific commodity was not the best possible would result in a recommendation that the tariff should be modified. Thus developments in commerce, not developments in politics, would determine when and how the tariff should be modified. It is rather an elementary proposition that the tariff should be controlled by such influences, but there are various elementary principles that have thus far been ignored in the conduct of the Federal government.

That a tariff commission principle in the making of Schedule C of the tariff is particularly welcome at this time to the steel industry is due to the mental position of the steel industry itself. Hitherto the steel manufacturers have appeared at least to know what they wanted. As individuals they have expressed strong convictions in hearings of the Ways and Means Committee of the House and the Finance Committee of the Senate. It is true the convictions of the various individuals did not always harmonize, largely from insufficient rehearsal, one may surmise, but the fact remains that the steel men have claimed to know what they wanted. They even cited figures to prove it.

Now their position is different. There are no competitive conditions now. We are shipping steel to certain countries that formerly tried to get into our own domestic market, and would gladly ship steel, if conditions permitted, to one country that has been the greatest steel exporter of all. American steel manufacturers do not know what competitive conditions will be like after the war. There are speculations of various sorts. Everything is uncertain. No one could determine now what rates would be best. What is needed is a system whereby the tariff rates will be quickly and sensitively responsive to conditions that develop when the war ends. To create and maintain such a tariff the commission seems the best that could be adopted. The establishment of the commission will be only the veriest beginning. A tremendous responsibility will rest upon it, and in its conduct there should not be too much of the "celerity contempered with cunctation" referred to by a recent governor of Pennsylvania.

## War Prices, Smelting Schedules and Profits

We have become so accustomed to linking the war price of metals with high profits to producers that it is an anomaly to find a company that is not as prosperous under present conditions as it was a year ago with a normal metal market. One such case has come to our notice, and probably it could be duplicated. The company ships a concentrate containing lead, copper and silver, to the local plant of a large lead-smelting concern. The schedule of rates and charges is the one generally in force in a district of comparatively small mines and companies.

Comparing profit from shipments to-day and a year ago, a strange situation is revealed. On a recent shipment made when lead, silver and copper were quoted at abnormally high prices, 48 per cent of the gross market value of metals in concentrates was absorbed by the smelter, leaving the shipper 52 per cent. A year previous, when metals were at a much lower price, concentrate of about the same grade was shipped, but only 39 per cent of the gross market value of the metals was absorbed by the smelter, leaving the shipper 61 per cent. When the net return under the high price of metals was figured back to profit per ton of crude ore, the slight increase over a year ago was found insufficient to offset the greater cost per ton of labor, powder and other supplies.

In another case the shipper received only 49 per cent of the gross market value of the metals, figuring silver at 64 cents, lead at 7 and copper at 27, or $22.67 per ton. Calculating the return from the same concentrate under normal prices for metals, say silver at 53 cents, lead at 4 and copper at 14, the return to the shipper would have been $16.85. In other words, with silver advanced 11 cents per ounce, and lead and copper all but doubled in market value, the net increase to the shipper was but $5.82 cents per ton, or only about one-third more than he would have received at normal prices.

Two elements combine to produce this condition. The first is the obvious increase in the cost of operation. The second is the nature of the smelting schedule, which, while it is designed to encourage production when metal prices are low, enables the smelter to reap most of the benefit when they are high.

# Readers' Views and Comments

## The Time Factor and Catalysis in Human Affairs

*To the Editor of Metallurgical & Chemical Engineering*

Sir: Things are not going right in public affairs. Some features seem to be getting into the way of betterment, although the process appears almost inperceptible to the naked eye. For instance, in New York City there are thousands of children of school age that are unable to secure school accommodations. And yet, under the Wirt system, with some additional equipment, every child in New York could enjoy full school time and there would be facilities to spare. On the Board of Education there are earnest and sincere men of constructive mind and disposition. But the whole thing is tangled up with politics, the mayor lacks power, vested rights in the form of somebody's prospective profits stand in the way—and the children are growing up on the streets. There is money enough, there are schools enough, there is, indeed, everything in plenty except intelligence and character in a small part of the Board of Education—and time. A part of the board plays politics and holds back progress, but the board, as a whole, is intelligent enough. Trouble is, the city is too big, the board is too big and the whole system is too big to do anything at once. It looks as though New York would have a good public school system in time, but many children of the present generation are growing up just where they should not grow up.

A recent issue of "Commerce and Finance"—a very readable paper withal—tells under "Grafting on the State" the findings of the Brooklyn Young Men's Republican Club in regard to the expenditures of the representatives of the State of New York in connection with the Panama-Pacific Exposition. It was a little matter of $700,000. First there was a handsome temporary building put up that housed no exhibits. Dishes, silverware and glasses from Tiffany's cost $5168.25. Various banquets given there cost over $2000 each. Three New York State commissioners took trips to Europe "to get into touch with exhibitors" to no real purpose whatever. Any number of State officials and commissioners having nothing to do with the exposition took trips to California and back with their entire families—and charged everything to the pork barrel. A gentleman of the commission spent some time at Hotel Knickerbocker in New York and his expense account for three days was: Room, $21; restaurant. $63.03. It all came out of taxes.

For the week previous his expenditures were more modest, being as follows:

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Feb. | 14: | Breakfast.. | $4.85 | Lunch.. | $4.90 | Dinner.. | $7.85 |
| " | 15: | " .. | 4.65 | " .. | 4.75 | " .. | 7.60 |
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| " | 17: | " .. | 4.85 | " .. | 4.80 | " .. | 9.10 |
| " | 18: | " .. | 4.20 | " .. | 3.90 | " .. | 7.80 |
| " | 19: | " .. | 3.85 | " .. | 4.10 | " .. | 7.80 |
| " | 20: | " .. | 4.10 | " .. | ... | " .. | 7.90 |

all of which was charged up.

A dinner to the Hon. Seth Low cost $2402—at least that sum was charged to the State of New York for it, and we know that Mr. Low is the last man on earth to approve of that sort of thing. We doubt if he had knowledge that it was not a subscription dinner. For Governor Whitman and his suite a special train was chartered. The cost to the State was over $1000 a day, for twenty-four days.

Every member of the party ate over $25 worth of food per day—if the figures are correct. That is what the State of New York paid for. Now there are many State commissions that do nothing but junket on money gathered from taxes, but there are others, permanent ones, that are so well manned, that do such good work, and at such cost of time to the really able men who constitute them, that the waste of their unscrupulous colleagues is neutralized. In time such scandalous proceedings as the debauch of the Exposition Commission will cease. Trouble is, New York is a big State, and it takes time to get over these things. Time and then something else.

Some time ago reference was made in "Metallurgical & Chemical Engineering" to the present Congress, and it was noted that during the first seven days of its session there were many bills introduced of which 5 per cent were for the public welfare and 95 per cent were designed chiefly to give public money to private persons. The history of Congress since then has been very little better. We want so much from it in the way of progressive legislation that it would seem to be the part of wisdom to placate the gentlemen with kind words. We do not hesitate to say that there are some men there who deserve all praise, and who hold aloft ideals of patriotism and integrity in a way to do us all proud. To them we accord all praise. But Congress is not wholly made up of that sort. A large number of its members are loud-mouthed shysters and pettifoggers who are too blind to see, too stupid to think, too selfish to feel and totally unworthy to be intrusted with public affairs. The type of men that we, as citizens, have allowed to creep into elective offices without a protest is a shame to all of us. And unless an enlightened public conscience arises in its might and drives the men of subnormal character out of elective offices, there will be no better chance for decent business in this country than there is in Mexico. This is the part that is up to us as electors. Congress, as we have said before, is US, the people. It reflects *our* intelligence. If we improve in intelligence and character, so will Congress. If we drop off, Congress will increase in noise and decrease in mind. But whatever happens, owing to the great mass of people and the number of their representatives, the process is bound to be slow; very, very slow.

The time factor, however, is not stable. It is subject to remarkable acceleration by the catalytic action of public opinion. As soon as the public learns, for instance, that many millions of dollars of Uncle Sam's money is to be spent by State officials on, let us say, militia, and that without any adequate check upon the way in which it is to be expended, the State officials will have to produce the goods—will deliver soldiers instead of politicians with epaulettes and men who play at drill once a month.

If the income tax, for instance, touched small incomes, no matter how slightly, the chances are that public opinion would be aroused and the time factor in the elimination of graft would be reduced in an amazing measure. Catalysis in human affairs is a very interesting subject.

X. Y.

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**The National Fertilizer Association** will hold its twenty-third annual convention, together with the Southern Fertilizer Association at the Homestead, Hot Springs, Va., July 10 to 14.

## Cleveland Meeting of American Institute of Chemical Engineers

The eighth semi-annual meeting of the American Institute of Chemical Engineers, held in Cleveland, Ohio, from June 14 to 17, 1916, proved very enjoyable. It was probably the best attended meeting the Institute has held so far, while the local committees had provided an excellent program of entertainments.

### WEDNESDAY MORNING SESSION

The opening session was held in the Hotel Statler on Wednesday morning, June 15. The attendance at this session varied between 50 and 75. As President Rosengarten was unable to attend on account of a serious automobile accident, the meeting was called to order by Professor J. H. JAMES.

In his address of welcome Mr. RALPH L. FULLER, president of the Chamber of Commerce and vice-president of the Harshaw, Fuller & Goodwin Co., called attention to the large number and the variety of chemical industries in Cleveland and vicinity. He emphasized that these industries were in sore need of a protective tariff in view of the conditions likely to be met with after the war. He suggested the advisability of a concerted effort by the American Institute of Chemical Engineers and similar organizations toward securing adequate and effective protection for the chemical industries which have been started or largely expanded during the last few years to meet present conditions.

Secretary JOHN C. OLSEN of the Institute replied to Mr. Fuller and expressed his appreciation of the fact that the Institute had been welcomed to Cleveland by a chemical engineer and manufacturer equally familiar with technical and business problems. He thought the suggestion of the Institute taking active steps to endeavor to secure suitable tariff legislation was feasible.

The report of the treasurer, Dr. F. W. Frerichs of St. Louis, Mo., showed a very substantial balance on hand. The secretary reported that 27 applications for membership had been received since the winter meeting and nine new members had been elected.

The Committee on Meetings reported that invitations for the next winter meeting had been received from St. Louis and New York. New York appeared to be favored by those present.

A progress report was presented by the Committee on Patents of which Dr. Baekeland is chairman.

Two technical papers were then read and discussed.

Professor JOSEPH W. RICHARDS presented a paper on "the production of the rarer metals." This paper, which was of especial interest on account of various suggestions as to the lines along which improvements in the manufacture of the rarer metals are possible, is printed in full elsewhere in this issue.

In a paper by Professor E. E. WARE and R. E. CHRISTMAN on "the effect of storage on mixed paints" it was shown that deterioration in mixed paints is frequently due to the presence of zinc oxide.

### WEDNESDAY AFTERNOON EXCURSIONS

On Wednesday afternoon the Central Furnaces and the Semet-Solvay by-product coke-oven plant of the Cleveland Furnace Company were visited. The melting of the steel in open-hearth furnaces (of which there are 100 of 50-ton capacity), heating in soaking pits and passage through the rolling mills were seen. In order to obtain a uniform product, two mixers of 400 tons capacity are used. The Garrett continuous rod mill was inspected with interest, also a Bessemer converter in operation.

At the Semet-Solvay plant a bank of 100 ovens of 800 to 1000 tons daily capacity was inspected. Ammonia and light oils are recovered from the gas which is worked with petroleum to recover the light oils.

### WEDNESDAY EVENING SESSION

The evening session was held at the University Club, Professor J. H. James presiding.

The first paper presented dealt with "nitric acid sofistication," the author being Professor JAMES R. WITHROW. The examination of a shipment of nitric acid from which crystals of sodium nitrate had been deposited was the occasion for a study of the solubility of sodium nitrate in nitric acid of various strengths. It was found that as much as 6 per cent of this salt could be dissolved producing a considerable increase in specific gravity. The presence of considerable amounts of calcium chloride in muriatic acid was reported during the discussion.

A paper by Mr. HERMAN STABLER of the U. S. Geological Survey, on "water powers of the Western United States," gave a list of water powers which have been developed in the Western states, aggregating 1,396,000 hp. Most of this power is used for electric lighting, electric traction and general municipal purposes, but not for electrochemical industries. A list of possible developments aggregating 5,708,000 hp. was given.

In the discussion of this paper it was brought out, especially by Mr. F. A. LIDBURY, that on account of cost of transportation electrochemical industries cannot be located west of the Mississippi to supply the market of the East and Middle West. On account of the limited amount of power available at Niagara Falls electrochemical industries cannot expand there and are being relocated in Canada, France or Norway.

After the reading of the papers the members were entertained as guests of the local committee at a highly pleasant smoker with a musical program.

### THURSDAY EXCURSION

Thursday morning the members were taken by automobile to the ore docks of the Pennsylvania R. R. Much interest was shown in three Hulett unloaders which were transferring the ore from an ore boat to railroad cars. The capacity of the buckets is 17 tons. The best record for unloading an 11,800-ton boat is 3 hours and 35 minutes, including weighing and loading on cars; the usual time is 4 hours.

The Cleveland filtration plant was then visited. This plant is built for the treatment of 85 million gallons of water. The purification consists of precipitation and clarification with ferrous sulphate, sedimentation, rapid sand filtration and chlorination. Mechanical sand filters are installed.

The plant of the National Carbon Co. was then visited. Dr. W. C. Moore guided. At this plant the manufacture of electric arc carbons was inspected, special interest being shown in the carbons used for the flaming arc lamps. Interest was also shown in the brushes for electric dynamos. Fifty grades are being manufactured. The methods in use for testing these brushes were shown. The manufacture of dry cells and methods of testing were also shown.

Luncheon was served at the Case School of Applied Science, an address of welcome being made by Prof. F. A. MABERY, who gave a short account of the formation and development of the school. Secretary Olsen responded, stating that the chemical engineers recognized that the varied chemical industries of Cleveland owed much of their prosperity and existence to Case School, which had furnished the technical men who carried on the industries.

LECTURE ON SOUND

After luncheon the chemical engineers were entertained and instructed by an admirable lecture by Prof. D. C. MILLER on "sound." Special interest was shown in the phonodyke, an instrument devised and built by Dr. Miller by which the curve of any sound may be thrown on the screen. The audience was delighted to watch the ever-varying curves produced by the music of a phonograph as well as those produced by the cheers and encores which greeted Prof. Miller's wonderful achievement. The sound waves were magnified 40,000 times. The mirror of the phonodyke weighs 2 milligrams and can vibrate 12,000 times per second.

The physical and chemical laboratories were then inspected with great interest.

DINNER

The subscription dinner was held in the evening in the beautifully decorated library of Hotel Statler. About 65 were present. Prof. A. W. SMITH acted as toastmaster, introducing first Dr. WILLIAM C. MOORE, chairman of the local section of the American Chemical Society, who spoke of the work of the local chemists. Mr. F. H. LEE, of the Grasselli Chemical Co., and chairman of the local committee of arrangements for the meeting, spoke of the efforts of his committee to make the visitors welcome. Dr. T. B. WAGNER was introduced as the only ex-president of the Institute present at the meeting and amused the party by telling of his efforts to be relieved of the duties of being ex-president. Mr. JOHN C. HEBDEN related his experience in building the plant of the Federal Dyestuff and Chemical Co. at Kingsport, Tenn., which is now in successful operation. Prof. A. H. WHITE told many amusing stories and spoke very interestingly on progress in chemical engineering education at the University of Michigan. Secretary J. C. OLSEN, in a toast to the "Institute," emphasized the substantial growth of the Institute and its bright prospects for the future.

FRIDAY EXCURSIONS

On Friday the members were taken by automobile to the National Lamp Works of the General Electric Co. at Nela Park where incandescent lamp bulbs are blown. The glass furnaces were inspected and the clean and orderly condition of the entire plant was greatly admired. The time of blowing a bulb was found to be 20 seconds. The Smith gas producer used in the plant was then inspected.

The cutting and decorating of the globes was then shown as well as the method of testing the bulbs not only for life of the bulb, but also for candle power. Interest was shown in the photometric room, which is one of the best equipped in the world. Tests are made of the light emitted by the lamp at any angle with an accuracy of one-tenth of one per cent.

The research laboratories were then visited, where methods of producing artificial day light were shown.

FRIDAY AFTERNOON SESSION

The company then proceeded by automobile to the Country Club, where an elaborate lunch had been arranged for by the Grasselli Chemical Company in honor of the visiting chemical engineers.

After luncheon an illustrated lecture was given by Prof. EDWARD BARTOW on the experiments on purification of sewage by activated sludge which have been carried out at the University of Illinois. Analyses of the gases evolved show considerable oxidation of the carbon in the sewage.

The Cleveland experiment sewage disposal plant was then visited. Mr. R. Winslow Pratt acted as guide. A one million-gallon unit for the purification of sewage by means of activated sludge is in operation. The sewage is subjected to the air for about one hour, ¾ cu. ft. being used per gallon of sewage. The raw sewage contains about 98 parts of iron per million gallons. This iron is precipitated, giving the sludge a brown appearance. The sludge contains about 3.5 per cent nitrogen, 2 per cent phosphorus pentoxide, 0.23 per cent $K_2O$ and 7 per cent fat.

FRIDAY EVENING SESSION

On Friday evening a joint meeting with the Cleveland Section of the American Chemical Society was held at the Hotel Statler, Dr. T. B. WAGNER presiding. A paper on "acid-resisting alloys" by W. C. CORNELL was read and discussed at considerable length, Mr. F. A. LIDBURY spoke on "the electrochemical industries of the United States," and the report of the Committee of the New York Section of the American Chemical Society on Co-operation between Universities and Industries was read.

SATURDAY EXCURSION

On Saturday the members proceeded by a special trolley car to Akron, Ohio, where the works of the Goodrich Rubber Company were visited. The manufacture of automobile tires was first shown, including both cloth and the silvertown cord tires. The manufacture of waterproof clothing, conveyor belts and hood rubber articles was shown. Especial interest was taken in the very large jars for submarine batteries.

A complimentary luncheon was then served by the Goodrich Company at the Country Club. On return by trolley the meeting adjourned. The attendance, which was the largest in the history of the Institute, was unusually great in the Saturday excursion.

A fine program for the ladies was also carried through very successfully. It included an automobile trip to Lorain and Elyria, with complimentary supper at the Country Club at Elyria, also an automobile trip through the beautiful Cleveland park system and a theater party.

## Program of the Fall Meeting of American Electrochemical Society

The fall meeting of the American Electrochemical Society will be held in New York City on Sept. 28, 29 and 30, 1916, that is, on Thursday, Friday and Saturday of the week of the Second National Exposition of Chemical Industries. The outline of the program is as follows:

*Wednesday*, Sept. 27, evening: General Reception, with registration, at the Chemical Exposition, Grand Central Palace.

*Thursday*, Sept. 28, forenoon: Reading and Discussion of Papers. General subject: "Made in America."

Luncheon.

Afternoon: Visiting the Exposition.

Evening: *Complimentary Smoker.* An invitation will be extended to the members of the American Chemical Society and other visiting chemists and engineers.

*Friday*, Sept. 29, forenoon: Reading and Discussion of Papers.

Luncheon.

Afternoon: Visiting the Exposition.

Evening: *Subscription Dinner-Dance.*

*Saturday*, Sept. 30, forenoon: Reading and Discussion of Papers; possibly an excursion.

Luncheon.

Afternoon: Visiting the Exposition.

Mr. F. A. J. FitzGerald is president and Dr. Joseph W. Richards, Lehigh University, South Bethlehem, Pa., is secretary of the American Electrochemical Society.

The arrangements for the New York meeting are in the hands of the New York Section of which Dr. Colin G. Fink is chairman and Mr. J. Malcolm Muir, 239 West Thirty-ninth Street, New York, is secretary.

## The Western Metallurgical Field

### New Mill of the Federal Lead Company

The Federal Lead Co. is one of the largest operators in the lead district of southeast Missouri. In addition to the 5000-ton mill which it is already operating it now has under construction a new 2500-ton mill which will be in commission this fall. Preparations for this plant were begun on Aug. 4, 1915, and from present indications it will be in operation within a year of that date, which will be a creditable performance considering that virgin land had to be cleared, wagon roads and railroads built, temporary structures erected for the accommodation of workmen, and an entirely new community established.

The site is on a hillside, at the bottom of which is the shaft and coarse-crushing department. From the shaft the ore will be conveyed by belt to the gyratories and thence to Symons disc crushers. The product of the latter will discharge onto an inclined belt conveyor leading to the mill bins, where it will be distributed by cross-conveyor.

The foundation and substructure of the mill building, including ore bins and jig and table floors, are of reinforced concrete, and the superstructure is of steel, giving a plant that will be light, clean and conveniently arranged.

Profiting by past experience at the old mill and by the general changes that have taken place in concentration throughout the district, the company will have an extremely simple flow-sheet for the new mill. The crushed ore will be separated into sizes suitable for jigging, tabling and flotation, and will be treated on six Hancock jigs, forty tables and a flotation plant consisting of Door thickeners, Janney agitation machines and air cells.

### A Problem in Lead-Zinc Separation

A troublesome product made in varying quantity at the lead concentrating mills of southeast Missouri is a middling of zinc, lead and iron sulphides. The material makes its first appearance in the jigs, but is reground and retreated until finally it is discarded from the concentrating tables. At some of the mills it is separated and stored, awaiting future disposal; at others it is reground and redressed to yield a low-grade lead concentrate which is shipped to smelters. Mechanical methods have failed to make a satisfactory separation of the constituents of this material, and considerable experimenting has been done to determine an economical method of treatment. Roasting and magnetic separation do not give satisfactory results, nor does any system of grinding and concentration, either wet or dry. The minerals are so intimately associated that some hydrometallurgical scheme seems necessary for their separation and recovery, and further work is being done along this line in the hope of solving the problem. Possibly roasting and leaching would effect a separation of the two valuable metals, leaving lead in the residue and giving a solution of zinc for electrolysis.

### Flotation of Zinc Tailings at Joplin

The first individual flotation plant to operate on a commercial scale in the Joplin zinc district is that of the Mining & Flotation Company of Denver, under the direction of S. P. Warren who designed and erected the mill. The material treated is taken from an old tailing dump on a lease of the Granby company at Chitwood, and contains about one per cent of blende and a small quantity of galena. It is brought to the mill by teams and scrapers, dumped over a grizzly and elevated with water to a trommel screen of 1-mm. mesh. The oversize is discarded. The undersize is deslimed by an inclined screw conveyor giving a coarse sand discharge and slime overflow. The sand is classified and treated on four tables, while the slime is thickened in a V-box and pumped to the 6-cell flotation machine. An oil mixture, containing mainly pine oil, is added at the first cell and the mixture flows successively through the six cells of the machine. The tailing is discarded, but the frothy concentrate is dressed on a concentrating table in order to raise the grade in zinc. The table tailing and middling is returned to the flotation machine. About fifty per cent of the total mill production is made by flotation and the balance on the four tables. The mill is treating 80 tons of material in 10 hours and producing 1600 pounds of 50 per cent zinc concentrate.

### The Tungsten Situation in Colorado

Following the sharp reaction in tungsten prices which demoralized the market several weeks ago, there has been a gradual recovery, and the large producers are continuing operations as usual. The Primos Mining & Milling Co. has remodeled the crushing department of its large plant at Primos, abandoning the stamps which have been criticized on account of their production of slime. The same company is continuing the construction of a new mill at Crescent in Boulder county, and the Rare Metals Extraction Co., composed of Cripple Creek operators, also is building a new custom mill at Rollinsville, which is expected to be in operation by July 1.

In an effort to make themselves independent of an uncertain market for tungsten concentrates, some operators are investigating the possibilities of making ferro-tungsten. Thus far the proposal seems feasible, for power is at hand from the hydroelectric plant of the Colorado Power Co., and specially high-grade concentrates could be produced without difficulty. Current specifications or ferro-tungsten, which the local producers would have to meet, demand a specially low content in carbon and phosphorus. Other deleterious substances are sulphur and manganese. The following limits are imposed: Tungsten, not less than 70 per cent; carbon, not more than 0.6 per cent; phosphorus and sulphur, each not more than 0.05 per cent; manganese, not more than 1.0 per cent. In case the concentrates produced are not rich enough to yield a ferro-tungsten containing 70 per cent tungsten, it may be necessary to produce some tungstic acid to add to the charge. In addition to the proposal to make ferro-tungsten, there is also a possibility that tungsten metal in powdered form may be made from tungstic acid. The latter article is now produced in the district. The recent flurry in the market has impressed on operators the necessity of greater independence, and it is likely that they will not stop at making concentrates but will extend their operations to include a more finished product.

### Resolutions Favoring Nitrogen-Fixation Plant

At a recent meeting of engineering and scientific societies held in Denver, attention was directed to the importance of constructing in this country suitable manufacturing plants for the fixation of atmospheric nitrogen. A committee was appointed consisting of representatives of the national engineering

institutes, to draft resolutions for endorsement by the Colorado sections of those bodies, for presentation to Congress. These resolutions set forth the economic and industrial importance of nitrogen and its compounds, and urge upon Congress the necessity of action that will aid in the development of nitrogen-fixation plants, both by private enterprise and by the federal government. Congress is asked to appropriate $100,000,000 for the purpose. The resolutions have been submitted to the members of the Colorado bodies, and have been endorsed by several of them.

### Company Reports

The 1915 annual reports of the five important porphyry copper producers, **Utah, Ray Consolidated, Nevada Consolidated, Chino** and **Miami,** contain unusually interesting and important information, showing marked increase in efficiency of operation and decrease in cost of production, despite the fact that operations were not conducted at full capacity during the first part of the year. The following tabulation contains essential data on milling.

CONDENSED DATA FROM ANNUAL REPORTS, 1915, OF PORPHYRY COPPER COMPANIES

| | Utah Copper | Ray Cons. | Nevada Cons. | Chino | Miami |
|---|---|---|---|---|---|
| Ore reserves, tons | 390,000,000 | 71,911,475 | 50,525,289 | 90,000,000 | 35,140,000 |
| Ore reserves, % cu | 1.447 | 2.235 | 1.652 | 1.75 | 1.82 |
| Ore milled, tons | 8,494,300 | 2,848,969 | 3,081,520 | 2,379,800 | 1,348,122 |
| Ore milled, % cu | 1.434 | 1.673 | 1.540 | 2.155 | 2.17 |
| Ratio of concentration | ..... | ..... | 7.18 | 15.02 | ..... |
| Concentrates produced, % Cu | 19.17 | 19.29 | 7.77 | 21.55 | 41.91 |
| Percentage recovery | 64.13 | 64.11 | 70.18 | 66.59 | 75.17 |
| Copper produced, lb. | 156,207,376 | 62,540,196a | 62,726,651 | 65,293,893 | 41,832,059 |
| Cost of milling, c per ton | 34.02 | 50.86 | ..... | 54.19 | 57.94 |
| Cost of copper, c per lb. | {7.56b<br>{6.61c | {9.478b<br>{9.423c | {8.67b<br>{8.23c | {7.12b<br>{6.75c | .....<br>6.05d |

aIncludes 1,425,682 lb. from ore shipped direct to smelter.
bAverage net cost after making allowances for smelter deductions and crediting gold and silver values, etc.
cAverage net cost after crediting miscellaneous income.
dCost of refined copper in concentrates on cars at Miami.

In addition to the foregoing, the following items pertaining to the different companies may be given. The **Utah Copper Company** milled 1,252,295 tons more ore than in 1914, and for the last six months of 1915 the daily capacity was 26,537 tons, or 33 per cent above normal capacity. Investigative work was done looking toward the treatment of the oxidized capping which has been and is being removed from the sulphide ore bodies. A leaching plant has been authorized, with an initial capacity of from 2000 to 3000 tons per day, and arrangements have been made to participate equally with the Garfield Smelting Co. in financing the construction and operation of a sulphuric acid plant near the latter company's smelting works.

At the smelting plant of **Nevada Consolidated,** improvements were made in the roasting department, whereby the tonnage of concentrates calcined per furnace day averaged 86 tons, as against 76 in 1914. In the reverberatory department a considerable reduction in cost per ton of material treated was obtained. The cost of converting was the lowest ever obtained since the converters were blown in, being $9.76 per ton of blister copper. The grade of matte was considerably lower than during any other year, being 27.2 per cent copper.

Increase in tonnage treated was obtained by the **Chino** company during the last eight months of 1915, when an average of 1573 tons per section per day was treated.

The **Miami** company showed a marked increase in percentage recovery, from 69.93 per cent in 1914 to 75.17 per cent in 1915. The grade of concentrate also was increased from 39.31 per cent copper to 41.91 per cent. An experimental plant for the treatment of oxidized copper ore may be started in the near future. Laboratory results on this work have been encouraging.

## The Iron and Steel Market

The significant fact in the dullness of the steel market is that it has developed no weakness. On the contrary, the situation is clearly a strong one, and this is a fact that could not be well brought out in an active and steady market. There is absolutely no disposition on the part of mills to cut base prices of finished steel for forward deliveries. It is true that premiums for prompt and early deliveries have continued to dwindle, until now they are almost negligible, except in the case of plates.

Strictly new buying of steel products is very light, and there is also a decrease in the volume of specifications filed against current contracts. There will be a further decrease in the total volume after July 1, as a number of relatively low-priced contracts expire by limitation with the June quarter.

Export demand continues heavy. Since the early part of April the export demand has continuously been heavier than at any previous time since the war started, but there is this change, that a month or two ago by far the major part of the export demand came from the allied belligerents, whereas of late the demand from neutral countries has been much more pronounced. The demand from neutrals is in part a reflection of lower ocean freights and in part a reflection of the complete exhaustion of their steel. The opening of the war found the countries that are far removed from sources of supply with large stocks of steel, while the actual consumption was greatly reduced. In the early months of the war there were many who predicted that the real demands of neutral countries would not find expression in actual buying until more than a year had elapsed. In some quarters the opinion is expressed that the volume, in tonnage, of export business is greater than that of domestic.

The dull domestic market is generally expected to continue through August. Then there should be a resolution of forces. While the large mills are filled with business quite comfortably through the year, and to an extent into the new year, many of the smaller mills are filled only for two or three months. A continued dull market would necessitate their seeking additional business within two or three months, while on the other hand the development of an amount of fresh demand, quite moderate in proportion to the total capacity of the country, would probably find insufficient mill capacity open to meet it.

In prognostications for the future account must be taken of the fact that even at this time a considerable proportion of the steel being shipped is invoiced at relatively low prices, being in fulfillment of old orders. The present rate of consumption is not necessarily an index to the rate that would obtain were all consumers, down to the ultimate consumer, forced to pay the present mill prices for finished steel.

### Pig Iron

An unprecedented situation has developed in the Southern iron market. When the market was low last year a great deal of iron was bought speculatively, most of it in warrants. The typical speculative holder of pig iron warrants refuses to sell when the market is advancing, i.e., when consumers are buying pig iron, and insists upon selling when the market has stopped

advancing, i.e., when consumers will not buy. As a rule he thinks the pig iron market should absorb pig iron as the stock market absorbs stocks, but sometimes it will no do so. Ordinarily pig iron warrants can be disposed of, even in a dull market, at a slight concession from the furnace price, but in the past fortnight, as Southern iron offered by furnaces was declining slightly, to $14.50, Birmingham, warrants were sold at $13.50, and even in a few instances at $13. The effect of these transactions has been to block the regular business in Southern iron and to affect sentimentally the position of buyers of Northern iron. We quote: No. 2 foundry iron, delivered Philadelphia, $19.75 to $20.25; f. o. b. furnace, Buffalo, $18.50 to $19; delivered Cleveland, $19.30 to $19.80; f. o. b. furnace, Chicago, $19; f. o. b. Birmingham, $14.50 to $15 for furnace iron, warrant iron unquotable; f. o. b. valley furnaces, 95c higher delivered Pittsburgh; Bessemer, $21; basic, $18.25; foundry, $18.25 to $18.50; malleable, $18.25; forge, $18 to $18.25.

### Steel

The billet and sheet bar market is a trifle easier. Soft steel to be made to specifications as to size and analysis is not over $42 for Bessemer and $45 for open-hearth. Odd lots arising in the course of steel mill operations usually bring $2 to $3 a ton less, while nondescript material, chiefly second discards and rejections arising in the filling of shell steel orders, go at widely varying prices, according to whether they suit the requirements of a purchaser or are acceptable only because they are cheap.

## Non-Ferrous Metal Market

*Monday, June* 26.—Dullness has characterized the market for most of the metals during the last two weeks, and a general decline has taken place. This is especially true of copper, lead, spelter and antimony. The consumption of tin is very good, and although it has been declining, it shows signs of reacting and developing strength again.

*Copper.*—The copper market has been dull and weak and spot electrolytic has dropped about 1 cent per pound to 26.75 cents. Producers are not cutting their prices as they have no substantial amount of copper for sale for delivery earlier than the last of the year. The labor situation is largely responsible for the unsettled condition of the industry in a good many quarters.

Second hands are now quoting electrolytic at 26¼ cents for deliveries in July, August and September, and 26 cents for the last quarter. A considerable export inquiry is reported. Exports have been good this month and up to June 22 were 23,925 tons of 2240 lb.

*Tin.*—Straits tin declined steadily from 44.25 cents on June 12 to 39.25 cents on June 22, but on June 23, showed signs of an upward turn and advanced to 40.25. The consumption of tin is known to be very good, but the amount of spot tin offered for sale has been quite large and consumers would not buy extensively on a declining market. The foreign market has been weak up until June 23, and the weakness was reflected in our market.

Shipments of tin into this country up to June 23 were 4650 tons.

*Lead.*—The Trust price still remains at 7.00 cents with independents quoting 6.85 to 6.95. For the most part the market has been dull, although large export sales have been reported as recently made.

*Spelter.*—Spelter has been consistently dull and weak, and spot has declined to 12.00 cents, a drop of almost 2 cents in the last two weeks. The demand for futures which are quoted at 11 cents for September delivery is better than the demand for spot. Earlier deliveries range from 11 to 12 cents.

*Other Metals.*—Antimony continues dull and is now quoted at 18.50 with very little business done. Aluminium is an exception in the general market and is very strong at 64 cents for Virgin metal. Platinum is quoted at $75 per oz. with quicksilver at $76 per flask. Silver is quoted at 65⅜.

## Coming Meetings and Events

American Electro-Platers' Society, Cleveland, July 6-8.

National Fertilizer Association, Hot Springs, Va., July 10 to 14.

American Institute of Metals and American Foundrymen's Association, Foundrymen's Convention, Cleveland, Sept. 11-16.

American Institute of Mining Engineers, Arizona, Sept. 18-23.

Mining and Metallurgical Society of America, New York Section, New York, Sept. 21.

Second National Exposition of Chemical Industries, New York, Sept. 25-30.

American Chemical Society, New York, Sept. 25-30.

American Electrochemical Society, New York, Sept. 28-30.

## Court Orders Dissolution of Corn Products Refining Company

In the case of the Government versus Corn Products Refining Company, a decision has been rendered by the U. S. District Court.

The quite lengthy decree which had been written by Federal Judge Learned Hand sustains the Government's contention that the Corn Products Refining Co. constitutes a monopoly in restraint of trade under the terms of the Sherman law. The corporation is to be dissolved and a plan for dissolution filed with the Federal Trade Commission within 120 days.

This commission, acting as master in chancery, is to report in due time a plan for disuniting to the Federal Court.

It is expected that an appeal will be taken from the decision.

## Water Power Development

### Resolution of Joint Conference Committee of National Engineering Societies

The Joint Conference Committee of National Engineering Societies has addressed the following letter to the President, dated June 28, 1916:

"To the President, Washington, D. C.,

"I take pleasure in transmitting to you a copy of a resolution adopted by the Joint Conference Committee of National Engineering Societies at its meeting held on June 15, 1916: 'The Joint Conference Committee of National Engineering Societies believes that the development of the country's undeveloped water power will increase national prosperity; that private enterprise should be encouraged and stimulated to expedite such development; that unnecessary legal burdens should be removed and existing doubts as to the safety of investment eliminated. It commends to the support of engineers all efforts made to secure the fullest publicity as to the underlying facts regarding this subject.'

"The Societies by which this Committee was constituted are: The American Society of Civil Engineers, The American Institute of Mining Engineers, The Amer-

ican Society of Mechanical Engineers, and The American Institute of Electrical Engineers—therefore, it speaks in the name of about 30,000 engineers.

"Yours respectfully,

"CHARLES WARREN HUNT,

"Secretary."

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The Joint Conference Committee consists of Calvert Townley, chairman; Chas. Warren Hunt, secretary, and Robert Ridgeway, S. L. F. Deyo, Arthur M. Greene, Jr., D. S. Jacobus, Charles Whiting Baker, J. Parke Channing, Benjamin B. Lawrence, Bradley Stoughton, and William McClellan.

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## Atlantic City Meeting of American Society of Testing Materials

The nineteenth annual meeting of the American Society of Testing Materials was opened at the Hotel Traymore, Atlantic City, N. J., on Tuesday, June 27. The meetings have been held at Atlantic City for the last ten years.

At the beginning of the Tuesday session the attendance was 250, but at the end of the first day the registration had reached 325. President MANSFIELD MERRIMAN called the meeting to order. The annual report of the executive committee was read by Secretary Edgar Marburg. The chief features of this report were data showing a greater increase in membership in the Society during the last twelve months than in any preceding year (the Society now having 2071 members), an account of the continued good work of the standing committees which form such an important feature of the Society, a discussion of the eligibility of candidates for the nominating committee, and an account of the provisions formally agreed to between the U. S. Department of Commerce and the Society. A resolution was passed that any member who had served the previous year could not serve again on the nominating committee until one year had elapsed, except the three past presidents who automatically become members. The report also included a discussion of the most important matters brought up at meetings of the executive committee during the last two years and a proposal to publish the Year-Book of Standards biennially, instead of once a year. This was voted upon by the Society and passed.

Several reports of standing committees were then read. That on Standing Committees, E-5, was read by Edgar Marburg, chairman; that on Wrought Iron, A-2, by S. V. Hummings, chairman; that on Papers and Publications, E-6, by Edgar Marburg, chairman. The committee on Standing Committees recommended a greater simplicity in the designation of technical committees and standards and also devoted considerable attention to amendments to the Regulations Governing Standing Committees.

Following the committee reports the announcement of the annual election of officers was made. The new officers are as follows:

President, A. A. STEVENSON; vice-president, S. S. VOORHEES. Members of Executive Committee: W. H. BASSETT, JOHN BRUNNER, G. W. THOMPSON and F. E. TURNEAURE.

The Society's new president, who is vice-president of the Standard Steel Works Co. of Philadelphia, Pa., in accepting the chair said that he was the first producer to be elected to the office, and he thought that it was indicative of more cordial relations between the producer and the consumer. He said that it should be his endeavor, however, to conduct the office in a strictly impartial manner, and to sustain and forward the work and ideals of the Society.

The afternoon meeting was presided over by General W. H. BIXBY, U. S. A., retired, and was given over entirely to committee reports, on miscellaneous materials. The report of Committee D-3, on Methods of Sampling and Analysis of Coal was read by S. W. Parr, chairman; the report on Committee D-5, on Coal by G. S. Pope, chairman; the report of the Committee on Shipping Containers by B. W. Dunn, chairman; the report of Committee D-11, on Rubber Products, by E. A. Barrier, chairman; the report of Committee D-13, on Textile Materials, by W. D. Hartshorne, chairman. All of these committees had been active and made important recommendations in their reports.

At the Tuesday evening meeting at which the new president A. A. Stevenson was in the chair, an address was presented by retiring President M. Merriman on the work of the committees of the Society. He emphasized that every member of the Society should be gratified at the results of the work of its technical committees. They have thrown new light on many problems of mechanics and strength of materials. Standards have been adopted which have promoted harmony between producer and consumer and which will be of great benefit to the industrial interests of the country. The Society now has thirty-seven committees.

The presentation of papers followed. An account of the same and of the proceedings of the following days is reserved for our next issue.

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## Industrial Preparedness the Subject of a Commencement Address

At the commencement exercises of the University of Pittsburgh Dr. Leo H. Baekeland delivered the commencement address on industrial preparedness, showing how the preparedness idea has brought forward a set of problems of national efficiency which are interconnected and in which chemistry plays a very important part. Almost every one of these problems is just as important in time of peace as in war. Preparedness against aggression is the best way of insuring the peaceful destiny of the country.

The honorary degree of Doctor of Chemistry was conferred on Dr. Leo H. Baekeland and Prof. J. O. Stieglitz.

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## Pay for National Guardsmen

In common with a large number of industrial concerns the McGraw Publishing Company, Inc., publisher of "Metallurgical and Chemical Engineering," as well as of "Engineering Record," "Electrical World," "Electric Railway Journal," and "Electrical Merchandising," is continuing payment of their regular salaries to those of its employees who are now members of the National Guard or Naval Reserve and who have been called into the service of the United States. As far as possible the employees will not only be kept on the payroll but their places will be kept open for them until the need of their military service will have ceased.

The good wishes of the whole organization go with them to the front. To those who have to stay at home it is left to continue to preach that the greatest preparedness-problem for this nation still remains to be solved—the problem of efficient nation-wide industrial preparedness.

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**Coke-Oven Accidents** is the title of Technical Paper 151 of the Bureau of Mines, the author being Albert H. Fay. The detailed report shows a gratifying decrease in the number of fatalities and injuries in 1915.

# Sources of Metal Loss in Copper Refining

BY LAWRENCE ADDICKS

It is only recently that the general question of metal losses in metallurgical practice has begun to receive anything like the attention it deserves. In any scheme of metallurgical treatment it is always easy to recover say 50 per cent of the value in an ore by some simple direct process. Then improvements are made which will bring the total recovery up to perhaps 65 per cent, but this additional 15 per cent has cost more per unit than the first 50 units. The process gradually develops until the additional complexity brings the operating cost up to a point where further recovery would cost more than the value of the additional metal recovered. It is also soon found that a 65 per cent process can profitably treat a leaner ore, and this adds another variable to the most economical efficiency equation.

Nor is the study of the various sources of metal loss a simple analysis of slag and stack losses although these are among the largest and most obvious sources. While this article deals with copper refining, or the separation of blister copper into fine copper, gold and silver, the method of examination will apply equally well to any other metallurgical process.

Fig. 1 gives a flow sheet of the process under consideration, reduced to its simplest terms. The sources of loss to be considered may be classified as follows:

A. *Weighing:*
   a. Incoming blister copper.
   b. Outgoing copper.
   c. Outgoing silver and gold.

B. *Sampling:*
   a. Moisture.
   b. Errors in method.
   c. Salting.

C. *Assaying*
   a. Assay methods.
   b. Splitting limits.
   c. Assay errors.

D. *Slags:*
   Cupola slag.

E. *Stack Losses:*
   a. Anode furnace stacks.
   b. Refining furnace stacks.
   c. Silver refinery stacks.
   d. Cupola stack.

F. *Process Losses:*
   a. Silver and gold in outgoing copper.
   b. Silver in outgoing gold.
   c. Gold in outgoing silver.
   d. Minor losses.
   e. Process margins.

G. *Handling Losses:*
   a. Wind losses.
   b. Theft.
   c. Solution losses.
   d. Soil losses.
   e. Slimes losses.

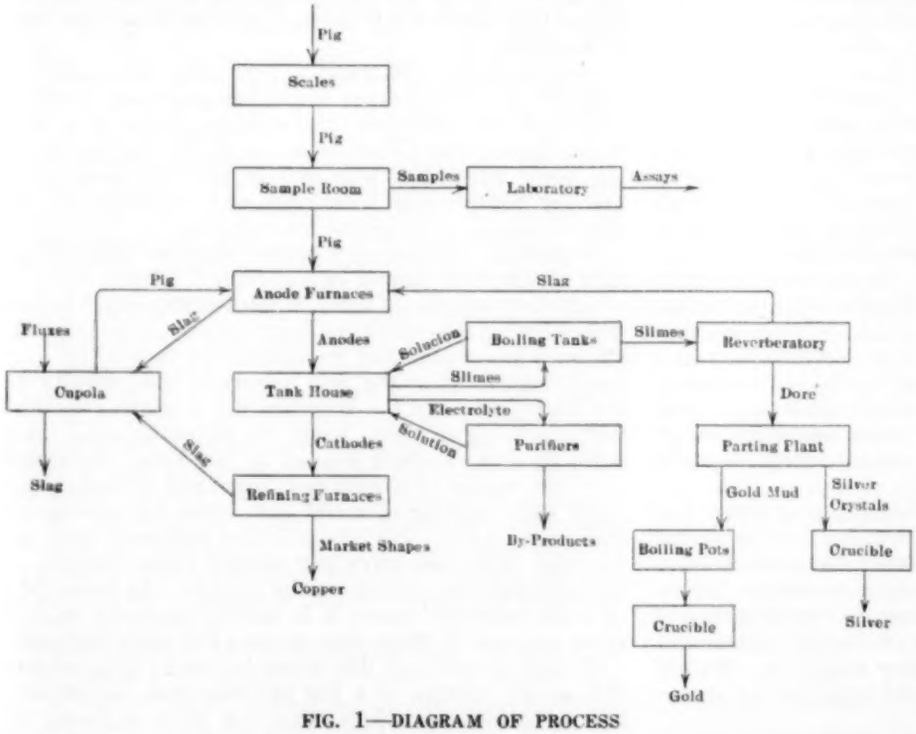


FIG. 1—DIAGRAM OF PROCESS

## A. Weighing

Scales are about the most precise pieces of physical apparatus we have. In the laboratory when we get a sensitiveness of 0.01 mg. with a capacity of 1 gram, we are working to 0.001 per cent and even lesser ratios are obtainable. In large-capacity scales the best precision obtainable is about 0.01 per cent; that is, if we want to be sure of the nearest pound we must not use drafts exceeding 10,000 lb. Using a 200,000-lb. railroad scale which to-day can be made distinctly responsive to a 20-lb. change in load gives the same precision, but does not equally satisfy a customer who places great stress on individual pounds.

It is, therefore, customary to weigh outgoing copper in 5-ton drafts under such conditions that the refineries have been able to stand upon their weights as final, provided the consignee agrees with the count of pieces. In order to accomplish this, two platform scales are placed in tandem, separate weighers taking readings and comparing figures before passing a lot. These scales are either of the overhung type where the knife edges are overhead and always in sight, or baby railroad scales. The latter are to be preferred as they are free from the obstructions above the floor line and it is possible to arrange the live platform so that an oncoming car divides the shock between two pairs of knife edges, greatly saving wear.

The standard of weight is furnished by the certification of the U. S. Bureau of Standards of a 50-lb. brass weight as a "Class B or Working Standard." Against this are checked a sufficient number of 50-lb. cast iron weights, adjustable by lead shot, to make up a full-scale load.

These weights are not suitable for every-day use as they afford a great surface for the condensation of moisture, collection of dirt, etc., so a test car loaded with very heavy cast iron weights is checked against them every two or three weeks and this test car is used for daily checks on the merchant scales. In this way it is quite practicable to maintain the desired precision of

1 lb. in 10,000. As identical methods are used for weighing incoming blister and outgoing wirebars there is but small chance of tracing any copper losses to scales in a modern plant.

In weighing the silver and gold the situation is somewhat different. The incoming silver and gold are weighed as blister copper as outlined above, while the outgoing shipments are weighed as bullion. As the gold is always shipped to a U. S. Assay Office whose weights are final, we again come to government standards and have automatically a weekly check against the refinery bullion balance. In one of the large refineries a year's returns showed a difference of but 0.0015 per cent. As a bullion balance is furnished with a set of weights instead of a sliding poise, it is comparatively easy to make mistakes in reading. To lessen this danger it is well to provide a direct-reading spring balance upon which a check to the nearest ounce can rapidly be made.

One of the most fruitful sources of error in weighing lies in the inaccurate taring of cars. Slight differences are bound to occur daily as the oil works out of the bearings but this is not serious. Wear and tear gradually lowers the weight of a car and it should be tared at least every ten days, the weight and date being painted on each side of the car and the rule adopted not to use any out-of-date cars. Similarly a car sent to the shop for repairs should have the weight painted out.

### B. Sampling

a. *Moisture.* It is generally assumed that copper carries no moisture. This question was first raised a good many years ago when some blister copper from Australia which had been more or less immersed in bilge water in transit was found to carry about 0.5 per cent of moisture. Pig copper is quite porous and a quart of water poured on the face of a pig will vanish as if absorbed by blotting paper. Some of the Western smelters are quenching their converter bars in boshes which brings this question up again. About all that can be done in such cases is to make careful tests in a drying oven on certain pigs and apply the correction found to the lots represented. It is evident that a very serious source of loss may pass unsuspected if this is not watched, as the refinery will be accounting for water as copper, silver and gold.

Then we have the question of weighing material that has been exposed to inclement weather. This should never be done, but sometimes it has to be done in order to save large delays, and it is then necessary to impose an arbitrary allowance by agreement. The weighing of hot wirebars does not seem to cause any appreciable error, the rising air currents being negligible. Weighing in the wind is more serious and scales should always be well protected.

b. *Errors in Sampling Method.* The silver and gold contents in a ton of blister copper may be worth anywhere from $10 to $500, although, fortunately for the refiner's peace of mind, there are very few very rich bullions. One hundred dollars per ton would be an ordinary figure, however. It can readily be seen that a small error in determining the true metal contents of blister copper would have an alarming effect upon the refiner's profits. A great deal of experimental work has therefore been done in developing standard sampling methods.

Blister copper usually runs 98 per cent to 99 per cent copper, the bessemerizing of matte having reduced the impurities to small values. The molten blister is poured into open molds and whether or not the copper is afterwards quenched in water it is always allowed to set before being removed from the mold. The pig therefore cools most rapidly on the sides and bottom, the heat being absorbed by the metal mold, and the last spot to cool is the upper central portion. The silver and gold and other impurities form a complicated series of solid solutions and eutectics with the copper, the richest portion in precious-metal values being the last to solidify.

It is evident that any system of sampling must bear this in mind. Theoretically this would require that when a sampling templet is laid out with a series of holes for drilling, these should be arranged to straddle and not pierce the center line of the pig, as no compensating holes can be drilled in the absolute edge of the piece. Practically this does not seem of great importance as experiments have shown that the richest zone often lies in a ring around the center rather than in the actual center, but it is still wiser to follow the proper practice as different combinations of impurities produce quite different results.

The old-style pig, shaped more or less like a loaf of bread, is now no longer in use except in South America where purchases of bullion are generally made by lot at auction rather than by contract. These old pigs were 6 in. thick and the segregation defied accurate sampling at a reasonable cost. The refineries have succeeded in introducing a bar about 18 by 27 in., 2½ or 3 in. thick, weighing about 300 lb., with just sufficient draft to facilitate removal from the mold and preferably unquenched. This readily yields an accurate sample, stacks well and is heavy enough to be an economical unit in handling.

The Japanese still make a very small pig weighing some 50 lb. These cause heavy sampling and handling costs and are therefore undesirable. Once in a long while copper comes from some out-of-the-way corner of the world which has been cast in pots and these cases call for considerable knowledge and ingenuity on the part of those in charge of the sampling.

A number of other precautions must be taken to secure an accurate sample of pig copper. There must be a sufficient number of holes in the templet—that is, one hole must not represent too large an area, otherwise experience has shown that the sample will be too high. In fact, careless sampling will generally give results on the high side. On the standard pig a quarter templet with forty-eight ½-in. holes is generally used; this gives an area of about 2½ sq. in. per hole. Each hole is in the center of a rectangle, arranged so that forty-eight such rectangles would just cover one-quarter of the area of a pig. The hole is drilled completely through the pig, each successive pig sample being marked at the next hole in rotation on the templet. In these days of large converter pours it is seldom necessary to drill every pig, one in three, four or even five being sufficient.

It must be realized that there is always more or less dirt on the surface of a pig and also that the set side has an oxide film which may run quite different in values from the body of the metal. It has been proved that decidedly different samples are obtained from a lot depending upon whether the pigs were drilled face up or face down, and further that while for a given brand of pig these differences are generally consistently in one direction, some brands would be the reverse of others. This dilemma has been met by using the so-called top and bottom method. Originally every other pig was turned bottom up, but it was found equally satisfactory to drill every other lot bottom up. No water or other lubricant should be used on the drill as this will tend to oxidize the hot drillings.

A splash sample taken at the smelter by collecting a fraction of the converter pour as shot in water will always show high metal values as against the refinery as such a sample is automatically freed of dirt and slag. For a long time the smelters felt that their splash samples were correct and that the refineries' samples low,

but it has been shown that a properly taken sample at the converter, using no water, can be made to check drill samples on the pig.

Enough has been said to show that sampling methods are a matter of the highest importance in any study of the sources of metal loss, as the refiner has to pay on the values shown by the sample whether or not they exist in the pig.

c. *Salting.* The contamination of a sample during preparation may cause serious errors and consequent apparent metal losses. Nowadays this is seldom done deliberately, although the large laboratories generally have one or two interesting stock tales of this character. It may easily be done unconsciously, however, if silver-refinery slags, doré samples, etc., are handled in the same department as incoming pig copper. The only sure way is to absolutely separate such different classes of work.

### C. Assaying

a. *Assay Methods.* In the early days an assay method was supposed to represent the process to be used and the assay value was admittedly lower than the true contents by an amount approximately equal to the expected loss in treatment In other words, the assay value was the recoverable value. To-day the tendency is to adopt methods which will give the highest result compatible with reliability but which still do not in all cases give full contents. The electrolytic assay for copper does give full value; in fact the chief danger in the handling of this method is that some impurities may be deposited on the cathode and weighed up as copper, to the disadvantage of the refiner.

The so-called uncorrected combination assay for silver in which the bullion is dissolved in nitric acid, the silver precipitated as chloride which in turn is scorified to gather the silver (and gold) into a lead button, the button being cupeled and the resultant lead weighed as silver plus gold, does not give full value of silver by from 2 to 3 per cent. The loss is due to values in scorifier slags, to cupel absorption and to volatilization. The main argument for this method is that when conscientiously run it will duplicate results very closely while there is at present no really satisfactory method of determining the absolute silver contents of foul bullion.

Skill is required in maintaining the proper temperature when cupeling; it must be hot enough to make the button "blick" at the finish, or it is not pure and other elements are weighed as silver; on the other hand it must be cool enough to show "feather" litharge around the edge of the cupel when finished, or the volatilization loss will be excessive.

Mismanagement in the laboratory may easily affect the apparent or financial metal losses. In some cases the "corrected" assay is used, where the losses in scorifier slags and cupels are determined and added, bringing the recovery up to about 99 per cent. Nothing is gained in accuracy and when once the particular bullion is known, the amounts of these losses are very constant and can just as well be allowed for arbitrarily in the refining terms, avoiding the expense and delay of determining daily corrections.

There is no practical way of ascertaining the volatilization loss except by running "proofs" made up with known quantities of silver. With high-grade doré and similar pure material this is satisfactory, but when various impurities are present, they affect the volatilization and a true proof would be a very complicated affair.

In the case of gold the fire assay, where the bullion is scorified direct to a lead button, is used as it gives a higher value than the gold parted from the silver in the combination assay, due probably to filter losses and the oxidation of some gold when dissolving the bullion in nitric acid in the latter method. This gives a return of about 99.6 per cent in the uncorrected assay. The corrected gold assay is very close to full value.

b. *Splitting Limits.* Were assays absolutely accurate and all laboratories equally reliable, the question of splitting limits would not enter into a discussion of metal losses. As such is not the case it is necessary to agree upon some reasonably allowable difference between buyer and seller within which assays shall be averaged or "split" and beyond which an umpire assayer shall be called upon.

In order to guard against either dishonesty or carelessness several simple precautions should be taken. In the first place assays should be exchanged simultaneously by mail; then all "reassays" to avoid umpires should be forbidden; finally, splitting limits should be made as close as possible. Sometimes the splitting limits are made very close, such as 0.1 per cent for copper, for example, and then only such umpires undertaken as may be necessary to bring the average results for ten consecutive lots within splitting distance.

The umpire should be considered simply as a substitute for one assayer, not as a source of authority. When two assays fall too far apart, the assumption is that one is incorrect and the umpire will determine which one it is. His result should therefore be averaged with the nearest original result unless it is above the higher or below the lower by more than the splitting limit, in which case the sample is pronounced uneven and the two original assays averaged for settlement.

In many cases where wild umpires are reported the trouble with the sample can be rectified by screening out the fines in the sample and then making up a portion for assay with just the proper proportion of fines, the more impure parts of the alloy having been brittle and pulverized under the drill.

It is also well to have two or three competent umpire chemists agreed upon, assigning umpires, as they become necessary, in rotation. This tends to check any inaccuracies in the umpire laboratory.

c. *Assay Errors.*—Assays are subject to three sources of error: (1) those of method; (2) those of procedure; (3) those of calculation, or clerical errors. The first has already been dealt with and may be classed as a voluntary error; the second may be due to carelessness, inaccurate apparatus, such as scale weights or burettes, or impure reagents; the third is more serious than might be imagined and constant vigilance is necessary. Perhaps the most common clerical error is that of reporting double or half the proper value in silver and gold determinations, due to failure to note the fraction of an assay ton taken for assay.

### D. Slags

We have now to pass from the apparent losses due to inaccurate accounting for values in the incoming bullion, to the actual metallurgical losses, and the first of these is the loss in the cupola slag. The anode and refining furnace operations produce a certain amount of slag due to the reaction between the metallic oxides formed during scorification in the furnace and silica and other oxides present in the furnace walls and hearth, or introduced as coal ashes blown over from the fire box, or as clay used in luting up the doors, fettling, etc.

In the old days of small furnaces constructed entirely of siliceous material, from 3 to 4 per cent of the weight of the charge was made in slag. In the large modern furnaces constructed partly or wholly of basic or neutral material and with much better fuel economy, the slag made is below 1 per cent.

Theoretically the slag should be a very small item. After a charge is melted air is blown in sufficient to oxidize part of the copper. This cuprous oxide in turn

displaces the impurities by oxidizing them and sending them into the slag. The cuprous oxide is soluble to a certain extent in the molten copper and were no acids present it would be theoretically possible to skim off simply these impurities with a little mechanically entangled copper. The actual slags made run about 45 per cent copper and must be treated in a blast furnace with fluxes such as iron oxide and limestone to make black copper unless a smelting plant is connected with the refinery.

If some sulphur is introduced into this charge a low-grade product running about 94 per cent copper may be made with a slag running below 1 per cent in copper, but this gives a high operating cost in the anode furnace.

If a high-grade black copper is made it is very difficult to get a slag below 2 per cent in copper. Taking a final cupola slag of 36 per cent silica and neglecting the small quantity of silica introduced by the basic fluxes, this means that every ton of silica which is allowed to find its way into the refining furnace slags carries away from 56 to 112 lb. of copper in cupola slag aside from the stack loss in this operation. It is evident therefore that this great source of loss is worthy of the most careful study, to the end that the least possible amount of slag be made at the reverberatories.

### E. Stack Losses

a. *Anode furnace stacks.*

b. *Refining furnace stacks.*

Not a great deal is known about these losses. The recoveries in flue dust from waste-heat boilers installed in anode furnaces show some 0.07 per cent of the copper treated, rather more of the silver and less of the gold. On the other hand, bag-house tests on the gases escaping from a high direct stack have shown less than this amount. The composition of the bullion under treatment has doubtless much to do with these losses, as the recoveries on furnaces treating cathodes are much less, due partly to less working of the molten charges and partly to the absence of volatile impurities which always promote metal losses.

c. *Silver refinery stacks.*—The anode slimes consist of the insoluble impurities contained in the anode and run 30 per cent to 40 per cent in silver. The copper is mostly leached out as sulphate and the slimes are then melted and subjected to a series of oxidizing operations until a high-grade doré is obtained.

In general about 1 per cent of the silver treated and about 0.1 per cent of the gold is recovered by various means in the flue system and great progress has been made in the last ten years in this practice.

Until the Cottrell system of electrostatic precipitation was successfully applied to treating these gases, the opportunities for serious undetected losses were very great and even now there is no point in a metal loss investigation which needs more careful watching.

The great difficulty is that the actual losses made are clearly discernible only after several years, as the results from single yearly inventories are always more or less clouded by anode furnace bottom absorptions which vary from year to year, and the punishment comes so long after the crime that it is very easy to be lax to the immediate benefit of apparent operating costs. Molten silver should be handled like a volatile liquid.

d. *Cupola Stack.*—This loss should be relatively small, as the operations are on a small scale and the charge in reasonably good physical condition. A proper dust chamber should be installed, however.

### F. Process Losses

a. *Silver and gold in outgoing copper.*—This loss is a perfectly definite one shown by daily assays. In general the loss runs from 0.5 to 0.8 per cent of the silver and gold present in the anodes. In the case of low-grade anodes this is not serious, but when rich material is being treated this loss becomes quite an item. The loss is due to slimes adhering to the cathode and is affected by the current density, the volume of circulation of the electrolyte, and the degree of refining given in the anode furnace.

b. *Silver in outgoing gold.*—The Government does not pay for the silver in gold deposited unless the fineness is low enough to require refining. In the latter case the refining charges imposed greatly exceed the costs of refining before shipment. The net result is that any silver contents are not paid for and therefore constitute a metal loss. This loss should not exceed two or three parts per thousand.

c. *Gold in outgoing silver.*—Any gold in outgoing fine silver is, of course, a total loss. It should be possible to keep this loss down to 0.1 oz. per ton of silver.

d. *Minor losses.*—These comprise values lost in any by-products sold, such as nickel sulphate, selenium, platinum, etc., and the value of assay samples sent out without credit, etc. These sources of loss are relatively unimportant but should not be overlooked.

e. *Process margins.*—These are negative losses or gains due to receiving more metal than accounted for, or to shipping less, due to trade customs. In copper there is no assay margin, but there is a gain of about 0.07 per cent due to the fact that wirebar copper runs but about 99.93 per cent copper, while it is credited as 100 per cent against incoming copper received on actual contents.

In the case of silver the uncorrected combination assay allows the refiner about 2.5 per cent margin while on shipments of fine silver, although the assay used shows true contents, a fineness of 999 is considered a 100 per cent delivery. With gold there is a margin of about 0.4 per cent in the incoming bullion from the fire assay used, but no margin in the outgoing fine gold.

### G. Handling Losses

a. *Wind losses.*—Wind does not cause as much trouble in a refinery as in a smelter, owing to the nature of the material handled. If the atmosphere were absolutely quiet, however, it is conceivable that the fume losses from stacks would settle down within the confines of the plant. Dust collected from the roofs of the buildings is always high in grade although very small in quantity. I have a memorandum of a sample of so-called dust swept up near a refinery furnace building which ran 65.81 per cent Cu, 49.8 oz. per-ton Ag and 3.41 oz. per ton Au.

b. *Theft.*—A refinery is always subject to losses by pilfering and a most thorough system of patrol, passes, etc., together with a policy of prosecution of all cases detected is necessary to hold this in check. Copper is a very easy metal to sell as junk and systematic carrying away of small quantities in lunch pails, etc., may run into surprising amounts. In the silver refinery it is customary to bond the employee and to have a double set of dressing rooms with different clothes for work and for outside wear, the men passing stripped before a watchman from one room to the other. One assistance in the detection of silver and gold thefts lies in the fineness of the products. When a man offers 999 silver or 24 carat gold for sale he at once arouses suspicion.

c. *Solution losses.*—Although the day has passed when electrolytes were purified by running a proportion to the sewer at regular intervals, there is still plenty of opportunity for loss in the handling of solutions.

It is very difficult to keep the electrolyte with its free sulphuric acid confined to the circulating system on ac-

count of tank leaks, overflows, etc., and it is even more difficult to build a permanent water-tight acid-proof floor under these tanks.

Some of the earlier refineries suffered severely from such losses and I know one plant where it was possible to dig a well anywhere in the vicinity and pump out water which gave a profitable copper recovery when passed over scrap iron.

One good way to keep track of losses from this and similar sources is to keep a careful record of sulphuric acid movements in the solutions. Serious acid losses point at once to equivalent copper solution losses. In plants where waste liquors are worked up by cementation upon iron there is an additional opportunity for loss in undertreated waste liquors.

d. *Soil losses.*—Where a plant is unpaved there is always more or less metallic material ground into the earth and in a smelting plant the top soil becomes in time very good ore. In fact some of the smelters have been smelting this material during the recent high metal prices. In a refinery there is not the same opportunity for loss owing to the nature of the material handled and such a loss should be negligible except in the case of solution losses mentioned above and that of slimes losses taken up below.

e. *Slimes losses.*—Mechanical losses of slimes could, of course, be assigned to the several sub-headings preceding, but the matter is so important that a separate paragraph has been reserved for their discussion.

Slimes originate in the tank house. They are periodically sluiced down into a screening tank whence they are usually transferred by pumping to a receiving tank in the silver refinery. A certain amount is carried out in the cathodes, a matter which has already been taken up. More or less adheres to the anode scrap when it is drawn and is removed as thoroughly as possible by scrubbing or by high-pressure water-sprays before the scrap is sent to the anode furnace. Any carelessness here may result in wind and soil losses in transit or up the stack during melting.

Tank leaks in the tank house carry considerable quantities of slimes to the cellar floor. While most of these values are recovered by washing the floor, some is absorbed and the floor material has to be smelted whenever extensive repairs are made.

In the silver building the slimes of necessity get spilled around to a certain extent and as boiling operations are conducted in this department the steam makes a sort of paste with them and care must be taken that all unnecessary walking in and out of this department be avoided, and that proper means for wiping shoes be provided. The shower baths used by the workmen should drain into the general wash water system.

The very best possible floor must be provided in this building. During some changes in one of the silver refineries some old foundations yielded up an absorption of 17,000 oz. of silver and 200 oz. of gold.

The slimes before melting have the appearance of black mud and it is very hard to get workmen to handle them with the care they instinctively give to the silver sponge and other metallic products produced later.

From the foregoing it will be appreciated that constant thoughtful attention in a great many directions is necessary to make a minimum metal loss. As the precautions all cost money it raises the question whether the additional saving due to them pays. The answer to this is that it is only by constant schooling in all these precautionary measures that men can be trained to be really careful when they are on their own responsibility and not under observation. For this reason the liberal use of white paint and many other seeming extravagances are justified. The same rigid care and supervision in the weighing, sampling, and assaying is required as in the control of slag and cathode losses, and careful attention must be given on general principles to all the apparently insignificant sources of indefinite loss.

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## The Formation of Aromatic Compounds from the Cracking of a Gas Oil

BY GUSTAV EGLOFF AND THOMAS J. TWOMEY

The commercial yields of aromatic compounds from the thermal decomposition of a gas oil at atmospheric pressure have not been given in the literature, although many processes as the Pintsch gas and oil gas machines have been using gas oil for years, forming the products aliphatic and aromatic hydrocarbons, permanent gases and carbon. The enormously increased demand for the substances benzene and toluene, due to the European war, emphasizes the necessity of having clear-cut information as to the number of gallons of benzene and toluene which would be produced from 100 gal. of gas oil used. It is hoped that this research will add to our information as to the yields of the aromatic hydrocarbons, benzene and toluene, from the cracking of a gas oil at atmospheric pressure and various temperatures at constant rate of oil flow into the cracking area.

The gas oil was pumped from a storage tank, passing through a calibrated oil meter into a gas-heated steel tube of 11.6 ft. in length and 8 in. in diameter, which was held at the temperature of the experiment. The gas oil was immediately vaporized in the upper portion of the tube, and the vapor passing through the heated zone was cracked into lower boiling aliphatic and aromatic hydrocarbons, permanent gases and carbon. The cracked vapor in part passes downward out of the sphere of the reaction through a coil condenser, the balance condenses in the air-cooled carbon pot at the bottom of the steel tube. The cracked oil from the condenser and carbon pot are mixed and a sample taken for analysis.

The oil used is what is termed commercially a gas oil derived from Pennsylvania crude petroleum. The gas oil had a boiling range of 90 per cent between the temperatures 200 deg. C. and 350 deg. C. The specific gravity of the starting oil at 15.0 deg. C. was 0.841, using a Westphal balance. The distillation was made with a Standard 100 c.c. Engler flask.

| Temperature | Per Cent by Volume | Specific Gravity |
|---|---|---|
| 0°—200° C. | 3.9 | .... |
| 200°—250° C. | 8.9 | 0.768 |
| 250°—300° C. | 46.2 | 0.825 |
| 300°—350° C. | 35.4 | 0.849 |
| Residue | 5.6 | .... |

In each experiment 20 gal. of oil were used.

The oil was cracked at five temperatures, 1100 deg. Fahr., 1200 deg. Fahr., 1300 deg. Fahr., 1400 deg. Fahr. and 1500 deg. Fahr. The gallons of oil flow into the cracking area was held approximately constant at 12 gal. per hour. In each experiment the number of gallons used was 20, and was measured with an oil meter which had been calibrated. The temperature of the reaction was determined by the use of a pyrometer, and registered the temperature upon the outside of the steel tube. Very careful temperature control was maintained as far as practical. The temperature variation was never greater than plus or minus 10 deg. Fahr.

The analysis of the cracked oil was conducted according to a method devised by the authors.[1] The procedure was to distill the cracked oil by use of an efficient fractionating column to 170 deg. C. This cut is refraction-

[1] Rittman, Twomey and Egloff: MET. AND CHEM. ENG'ING, 13, 682 (1915).

ated and analyzed for its benzene, toluene and xylene content by distillation cuts and specific gravity.

The specific gravities of the cuts were taken by means of a Westphal balance at 15.0 deg. C.

### Experimental Data

The experimental data follows in the form of tables and graphs.

Table 1 and Fig. 1 show the effect of temperature on the per cent of recovered oil and specific gravity of recovered oil.

TABLE I—THE EFFECT OF TEMPERATURE AT ATMOSPHERIC PRESSURE ON THE PER CENT OF RECOVERED OIL AND THE SPECIFIC GRAVITY OF RECOVERED OIL

| Temp. | Per Cent of Recov. Oil | Specific Gravity |
|---|---|---|
| 1100° F. | 72.0 | 0.857 |
| 1200° F. | 60.8 | 0.883 |
| 1300° F. | 44.5 | 0.935 |
| 1400° F. | 39.0 | 0.979 |
| 1500° F. | 34.5 | 0.987 |

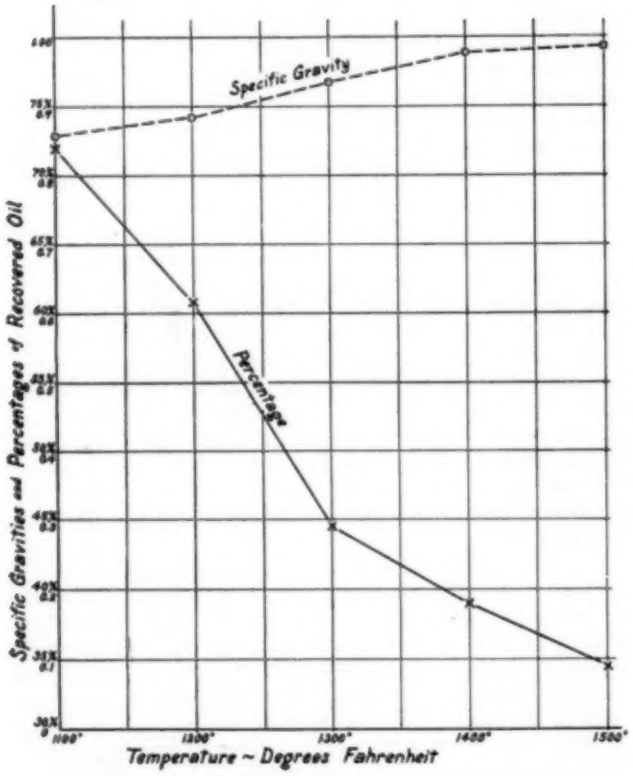


FIG. 1—THE EFFECT OF TEMPERATURE AT ATMOSPHERIC PRESSURE ON THE PER CENT OF THE RECOVERED OIL AND THE SPECIFIC GRAVITY OF THE RECOVERED OIL

TABLE II—THE EFFECT OF TEMPERATURE ON THE FORMATION OF BENZENE, TOLUENE AND XYLENE IN THE RECOVERED OIL

| Temp. | Per Cent Benzene | Per Cent Toluene | Per Cent Xylene |
|---|---|---|---|
| 1100° F. | 0.4 | 2.0 | 2.2 |
| 1200° F. | 0.9 | 3.0 | 3.1 |
| 1300° F. | 4.1 | 6.7 | 5.8 |
| 1400° F. | 8.4 | 8.5 | 6.5 |
| 1500° F. | 8.5 | 7.0 | 6.8 |

TABLE III—THE EFFECT OF TEMPERATURE ON THE FORMATION OF BENZENE, TOLUENE AND XYLENE ON THE BASIS OF OIL USED

| Temp. | Per Cent Benzene | Per Cent Toluene | Per Cent Xylene |
|---|---|---|---|
| 1100° F. | 0.3 | 1.4 | 1.5 |
| 1200° F. | 0.6 | 2.1 | 2.2 |
| 1300° F. | 1.8 | 2.8 | 2.6 |
| 1400° F. | 3.3 | 3.2 | 2.5 |
| 1500° F. | 2.9 | 2.3 | 2.3 |

Table 2 and Fig. 2 show the effect of temperature on the formation of benzene, toluene and xylene in the recovered oil.

Table 3 and Fig. 3 show the effect of temperature

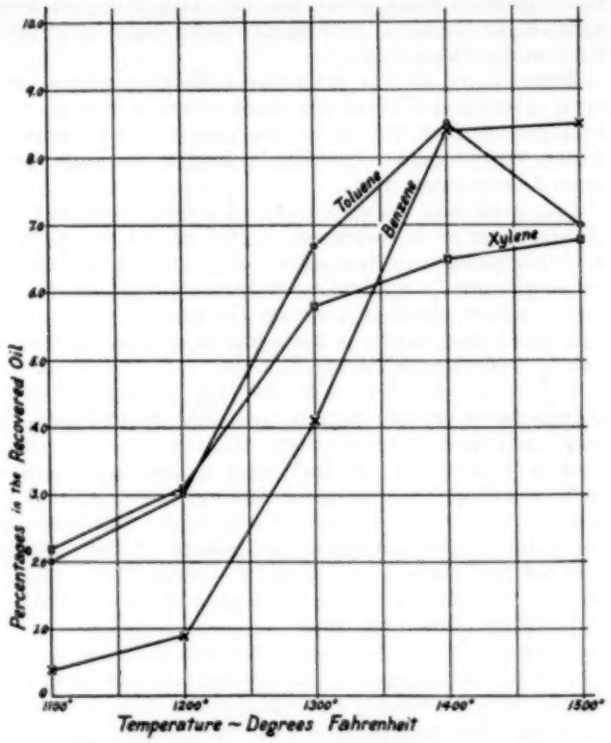


FIG. 2—THE EFFECT OF TEMPERATURE ON THE FORMATION OF BENZENE, TOLUENE AND XYLENE IN THE RECOVERED OIL

on the formation of benzene, toluene and xylene on the basis of oil used.

Table 4 and Fig. 4 show the effect of temperature on the distillate to 170 deg. C. and the specific gravity of the distillate.

Table 5 and Fig. 5 show the effect of temperature on the specific gravity of the benzene, toluene and xylene cuts.

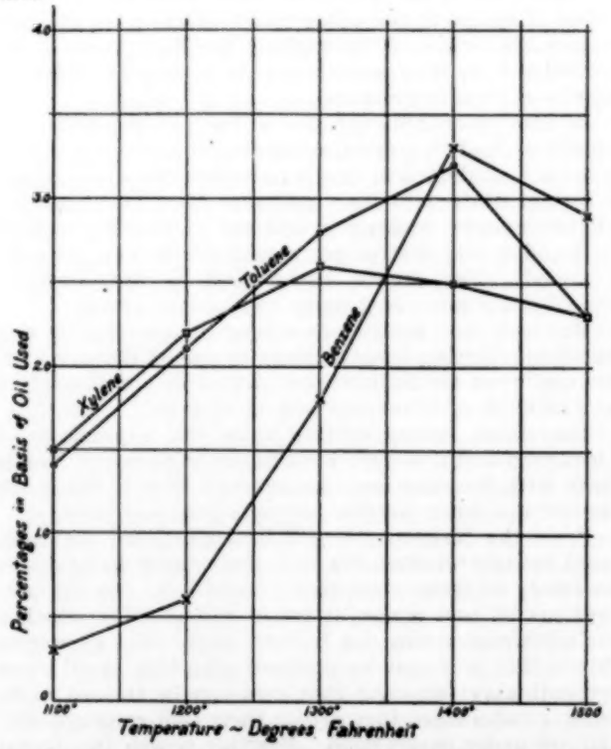


FIG. 3—THE EFFECT OF TEMPERATURE ON THE FORMATION OF BENZENE, TOLUENE AND XYLENE ON THE BASIS OF OIL USED

## Discussion of Experimental Data

### A. THE EFFECT OF TEMPERATURE ON THE PER CENT OF RECOVERED OIL AND SPECIFIC GRAVITY OF RECOVERED OIL

A paraffin base oil when subjected to thermal decomposition in the vapor phase yields permanent gases, carbon, and a liquid which is widely different in constitution from the original starting oil. It contains some high molecular weight paraffins; lighter molecular weight paraffins; olefins and aromatic hydrocarbons of the type benzene, toluene and xylene.

From Fig. 1 it will be noted that as the temperature increases the decomposition of the oil increases, most markedly between the temperatures 1200 deg. and 1300 deg. Fahr.

The specific gravity of the cracked oil increases with increase of temperature. At 1100 deg. Fahr only a slight difference will be noted from the gravity of the starting oil. This would indicate that only a small amount of cracking takes place at this temperature. The greatest change takes place between the temperature limits of 1200 deg. and 1300 deg. Fahr., which are also the temperature limits which give the highest decomposition of the original oil.

### B. THE EFFECT OF TEMPERATURE ON THE FORMATION OF BENZENE, TOLUENE AND XYLENE IN THE RECOVERED OIL

In the thermal decomposition of gas oil the formation of xylene proceeds more rapidly than either benzene or toluene at the lower temperatures. As the temperature is increased to 1400 deg. Fahr. the benzene and toluene content of the recovered oil increases rapidly, whereas the xylene falls off considerably. The maximum amounts of benzene, toluene and xylene are: 8.5 per cent benzene at 1500 deg. Fahr.; toluene, 8.5 per cent at 1400 deg. Fahr., and 6.8 per cent xylene at 1500 deg. Fahr.

TABLE IV—THE EFFECT OF TEMPERATURE ON THE DISTILLATE TO 170° C. AND THE SPECIFIC GRAVITY OF THE DISTILLATE

| Temp. | Per Cent to 170° C. | Specific Gravity |
|---|---|---|
| 1100° F. | 20.8 | 0.770 |
| 1200° F. | 25.8 | 0.788 |
| 1300° F. | 28.7 | 0.823 |
| 1400° F. | 29.1 | 0.860 |
| 1500° F. | 27.6 | 0.860 |

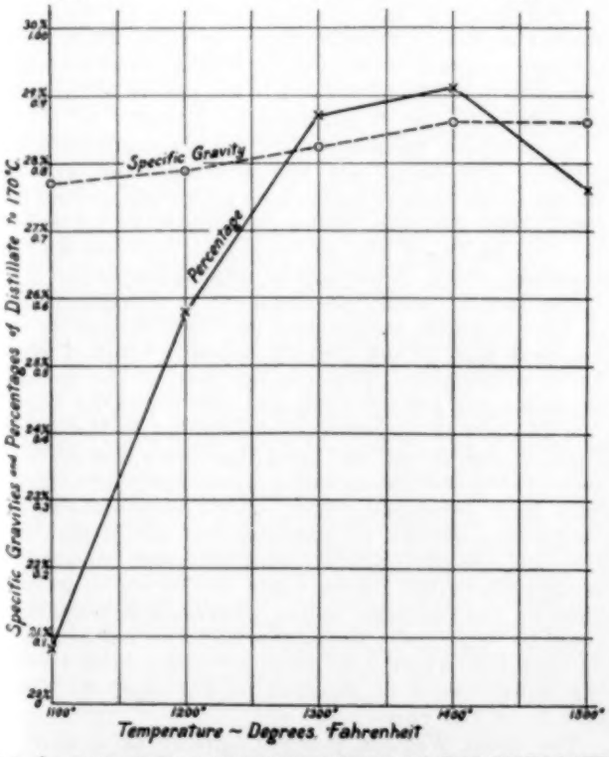


FIG. 4—THE EFFECT OF TEMPERATURE ON THE DISTILLATE TO 170 DEG. C. AND THE SPECIFIC GRAVITY OF THE DISTILLATE

### C. THE EFFECT OF TEMPERATURE ON THE FORMATION OF BENZENE, TOLUENE AND XYLENE ON THE BASIS OF OIL USED

Commercially the interesting and most important fact of cracking gas oils at present are: how many gallons benzene, toluene and xylene can one make from 100 gal. of gas oil? The maximum formation of benzene was found to be 3.3 gal. per 100 gal. of oil used. Toluene yield was 3.2 gal. and xylene 2.5 gal. for each 100 gal. of oil used. In other words, 9 gal. of valuable aromatic compounds from 100 gal. of paraffin-base gas oil.

### D. THE EFFECT OF TEMPERATURE ON THE DISTILLATE TO 170 DEG. C. AND THE SPECIFIC GRAVITY OF THE DISTILLATE

The light oil distillate to 170 deg. C. contains all of the benzene, toluene and xylene. It will be noted that as the temperature increases the per cent of distillate to 170 deg. C. increases to a maximum and then decreases. The gravity also increases with increase of temperature, and indicates the greater decomposition of the paraffin hydrocarbons to aromatic compounds.

### E. THE EFFECT OF TEMPERATURE ON THE SPECIFIC GRAVITY OF THE BENZENE, TOLUENE AND XYLENE CUTS

The specific gravity of the cuts of benzene, toluene and xylene indicates the relative freedom from like boiling point hydrocarbons of the paraffin series, which

TABLE V—THE EFFECT OF TEMPERATURE ON THE SPECIFIC GRAVITY OF THE BENZENE, TOLUENE AND XYLENE CUTS

| Temp. | Benzene Cut, Sp. Gr. | Toluene Cut, Sp. Gr. | Xylene Cut, Sp. Gr. |
|---|---|---|---|
| 1100° F. | 0.734 | 0.787 | .... |
| 1200° F. | 0.740 | 0.798 | 0.816 |
| 1300° F. | 0.796 | 0.840 | 0.850 |
| 1400° F. | 0.850 | 0.866 | 0.875 |
| 1500° F. | 0.874 | 0.864 | 0.867 |

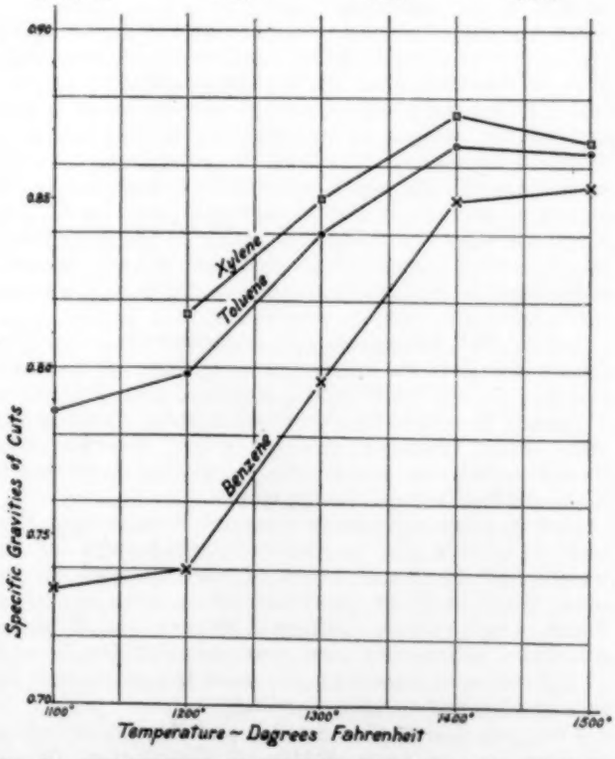


FIG. 5—THE EFFECT OF TEMPERATURE ON THE SPECIFIC GRAVITY OF THE BENZENE, TOLUENE AND XYLENE CUTS

cannot be removed by any physicochemical means. Trinitrotoluene and phenol can be readily made from the toluene and benzene which are formed from the decomposition of a paraffin-base gas oil.

SUMMARY

1. The greatest decomposition of the gas oil used takes place between the temperatures of 1200 deg. Fahr. and 1300 deg. Fahr.

2. The maximum amounts of benzene, toluene and xylene in the recovered oil are: benzene, 8.5 per cent at 1500 deg. Fahr.; 8.5 per cent toluene at 1400 deg. Fahr., and 6.8 per cent xylene at 1500 deg. Fahr.

3. It has been shown that at atmospheric pressure and 1400 deg. Fahr. in a steel tube 11.6 ft. in length and 8 in. in diameter, that 100 gal. of the gas oil used will produce 3.3 gal. of benzene, 3.2 gal. of toluene, and 2.5 gal. of xylene.

4. It has been shown that the benzene, toluene and xylene, relatively free from paraffin hydrocarbons, can be produced from the cracking of a gas oil.

## Electrochemical Possibilities of the Pacific Coast States as Compared with Those of Sweden and Norway*

BY J. W. BECKMAN

To some of us the word electrochemistry has a mystic charm; it produces visions to the mind's eye of turbulent streams and waterfalls in the midst of peaceful forests, and also the vision of the electric furnace with its sputtering frenzy. It is a wide step from the waterfalls in the woods to the wild roaring of an electric furnace, but we all know that they stand in intimate relationship to each other. The power of the impetuously falling water is harnessed and transferred often hundreds of miles, silently and calmly over a wire, only to be let loose at the other end in often a wild though conquered shape, to produce products which a complex civilization has learned to be dependent upon.

To-day there may be dreamers who have visions of cheap electric power being produced in a way other than by water power. It may be possible to do this, but for the big electrochemical industries of to-day, and of the future, hydraulically produced power is and will be used. Therefore, the most important raw materials of all electrochemical industries is an abundant amount of water seeking a lower level. Few locations offer conditions favorable to the harnessing of water for industrial purposes, and as a rule the mountainous countries are the water-power producing localities.

Lands that are known as hydroelectric power producers are various mountainous sections of Southern Europe as well as Sweden, Norway, and Finland in Northern Europe. The Western sections of the North and South American continents are, together with New Zealand and a few other localities, favorable to hydroelectric power developments.

It may seem strange to compare Sweden and Norway, countries old in the civilized history of the world, and from our point of view located on the globe practically at the North Pole, with the three Pacific Coast States, California, Oregon and Washington, but I believe there are many similarities, in spite of difference in relative position on the globe, that are in many respects quite startling.

I beg you to note that Sweden and Norway are about as large as the three States of Washington, Oregon and California. The population in Sweden is about five millions, and the three coastal States contain practically the same number.

Sweden has large sections along the coast which are comparatively flat, consequently the water power sites are located mainly inland, much the way conditions are on the coast. One-half of Sweden is wooded, while half of these three States is under timber.

Geologically the conditions are very different. Sweden is practically all of very ancient geological formation, while the coast is, as we all know, of comparatively recent formation.

In a general way conditions in Norway are similar to those in Sweden. The land is heavily timbered and filled with inaccessible mountains and valleys. In many places the streams drop right into the ocean, making power developments possible on tidewater, similar to the possibilities on our own coast in British Columbia and Alaska. The geological formation in Norway is of the same age as in Sweden. Norway has about three million inhabitants, making a total of eight million inhabitants on the Scandinavian Peninsula.

The electrochemical possibilities in Sweden and Norway are great for two reasons only—one is abundance of cheap power, the other is comparatively cheap labor.

Seven and one-half million horsepower are available in Norway at present, of which one-half million is developed, and an additional million horsepower is under development. When this power is developed it will amount to about 20 per cent of all available power.

The largest present, single operating installation is at Rjukan, where 131,000 hp. are developed and at the same place 119,000 hp. are being developed, which is the largest power development under way there at present.

There are two developments possible in Norway, each for 240,000 hp., but neither of them is even projected to be developed. Many of the installations are in the interior and inaccessibly located, involving special means of transportation to reach them, often through sections of the country where power transmission is impossible, partly due to the nature of the country, and also due to climatic conditions.

However, in Sweden conditions are materially different. The heads are comparatively low and the nature of the country makes long transmission lines possible. The available power in Sweden is 6.2 million hp., of which at the present time 900,000 hp. are developed, about 15 per cent of total available power.

The largest single development in Sweden is that of the Swedish government at Trollhättan, in the Southern part of the country, where a total of 80,000 hp. is obtainable. The greater part of the Swedish developments are low-head and small-capacity plants.

If the power situation be considered in the Pacific Coast States, it will be found that there are available about 11,000,000 hp., of which 7 per cent or 831,000 hp., have been developed. Most of the developments are high-heads, 500 ft. or more—a few exceptions there are—and among the most noted proposed low-head developments on the Pacific Coast is The Dalles development on the Columbia River, where about 800,000 hp. could be delivered. More than half this amount could be supplied twelve months of the year. The remaining power could be counted on for eight to eleven months of the year.

The Great Western Power Company is, in spite of having developed some 100,000 hp., still able to develop some 500,000 hp.

On account of local and climatic conditions in the

*A paper read before the San Francisco Section of the American Chemical Society.

coastal states, long distance transmittal is easy and comparatively cheap.

As the population is centered in the large valleys and along the coastal districts, the necessary length of power lines from generating stations, located in the mountains, to the consuming districts, are comparatively short, and the lines with few exceptions do not exceed 200 miles.

The cost of hydroelectric power is really a question of bookkeeping, and since each individual power plant has its pet way of calculating costs, it is impossible to compare the average power costs given with each other, not knowing how much, or how little, they include, what the interest rates are, etc. When a standard accounting method is adopted by all power plants all over the world, then the comparing of cost, per horsepower, may have some meaning.

When an industry develops its own power source, the bookkeeping method can hide absolutely the actual cost of the power. On this account I am extremely sceptical as to the low figures quoted for the power some industries utilize in Norway.

The prices for power obtainable on this coast close to, or at the power site, do not vary materially from those in Sweden and Norway.

The prices in those countries are from about $6 per horsepower-year, and up, provided large blocks of power are taken. In Norway with higher head developments the minimum price may be somewhat lower.

Compare these prices with that of less than $10 per horsepower, quoted by the State of Oregon for power from the projected development at The Dalles, and I believe it will be agreed that cheap power is available here, as well as in Sweden and Norway.

Only recently the Great Western Power Co. has entered into contract with an electrochemical company, for large blocks of power on tidewater at a rate that is as good as that which is obtainable at Niagara Falls. Niagara Falls is 500 miles from tidewater, which means a long rail haul. Power on San Francisco Bay at the same rate, means large savings in the way of transportation charges, etc.

The idea that there is an abundance of cheap labor in Sweden and Norway is to an extent a fallacy. Emigration is continuously draining the working stock of the people, and although the average daily wage is about $1 to $1.25, there is not a superabundance of labor, and the industries are often handicapped. Of course, in the more specialized industries, as the electrochemical, the price for labor is somewhat higher.

Compared with the cost of labor on the Pacific Coast, the Scandinavian prices are low. But the ultimate cost of producing electrochemical products, I believe, is no higher there than here, due to higher cost of raw materials there than we have to pay.

What, then, are the industries that have brought Sweden and Norway to the front in the eyes of the world as countries that take a foremost position in the electrochemical industries?

When artificial nitrogen fertilizers are mentioned, Norway with its nearly 300,000 hp., exclusively devoted to that industry, looms up. Calcium nitrate and calcium cyanamide are both products made in Norway; the latter is also made in Sweden. The raw materials for these products are: cheap power, the nitrogen of the atmosphere, and limestone. In case of the cyanamide, coal is also needed. In Sweden and Norway, plentiful, cheap power is available, though not always in accessible places as the large developments at Rjukan, in Norway show, located as they are in the most impenetrable part of the mountain fastness. Nitrogen is abundant; limestone is accessible, in some cases, though involving considerable haul by rail or water. The coal is all brought in from England, which means expense of handling and in addition duty on the importations.

The Pacific Coast States are in this respect as favored in many instances, as the countries of the Scandinavian peninsular. Take, as an example, the projected development at The Dalles; deep-water navigation is possible up to and beyond the proposed power site; limestone from Washington could be brought in cheaply, quarried as it is right on tidewater; coal from China, and eventually from Alaska could also be brought in and water transportation would be available for the finished product.

Similar conditions can be found at other localities on the Pacific Coast.

What has been said in regard to the fertilizer industries applies equally well to the carbide industries. Sweden consumes some 20,000 hp. annually in carbide manufacture and Norway, though I have no definite figure, consumes considerably more at the large works at Odda.

The Swedish iron is famous and well known over the world. There was a time, however, until quite recently that Swedish iron was beginning to lose its reputation. Scarcity of charcoal followed the increasing numbers of shaft furnaces in operation until gradually some of the iron masters of Sweden began to substitute coke with charcoal and the common coke pig iron was obtained with a result that the long established position held by Swedish iron in the markets of the world was fast slipping away. To-day, though, it is possible to increase the number of shaft furnaces in Sweden to three times as many as at present, without being obliged to use coke.

The reason is the introduction of the electric shaft furnace, in which two-thirds of the charcoal used for heating the charge in the furnace are replaced by electric heat. As the earliest blast furnaces were built in Sweden, so also Sweden first successfully solved the electric shaft furnace.

The iron industry of Sweden is located in a narrow strip 70 miles wide and 140 miles long approximately, the distance from Oakland to Sacramento. This small section of the country has brought, through its iron, fame to Sweden. As time goes along and the old blast furnaces have to be replaced with new, never again will an old-type furnace be placed in operation. Electrical shaft furnaces will be installed instead. There are now over a dozen of these furnaces in operation in Sweden turning out close to 50,000 tons of iron per year. The raw materials needed in electric shaft-furnace operations are cheap power, high-grade iron ore, good limestone and an abundant supply of charcoal.

Close to 1,000,000 tons of charcoal are burnt in Sweden annually, a great part of which is used in the iron industries. The charcoal is burnt all over the country and shipped into the iron-producing district by rail.

The greater part of the charcoal is produced in the old-fashioned way of heap-burning, though there is a strong tendency at present to replace the heap-burning by the large-unit by-product charcoal ovens, of which there are over twenty plants installed and operated. In this connection let me mention that at the Panama-Pacific Exposition there was a very excellent exhibit in the Swedish Building, of raw materials used and finished products obtained from one of these by-product plants.

Norway is also heavily timbered, but due to very great transportation difficulties charcoal is not produced in such quantities there, nor do I believe they have any electric shaft furnaces in operation.

The iron ore is abundant in Sweden. Some has to be concentrated, since high contents of silica mean an excessive power consumption in the electric shaft furnace. The Northern ores from the large famous deposits near the Arctic circle average close to 70 per cent iron, and so do the concentrates from the more centrally located deposits.

Limestone is available though not always in close proximity to the shaft furnace plant.

Power is very often obtained from small hydroelectric developments, where enough energy is generated to operate a single furnace or purchased from a generating station.

What then are the conditions on the Western coast of the United States that would suggest the possibility of an iron industry growing up similar to that of Sweden.

The three coastal States have practically as much timber land as Sweden; the actual board measure would be much to the advantage of these States, since, due to climate and other conditions the growth in Sweden is quite light. Incidentally it is of interest to realize that Washington, Oregon, and California to-day contain about one-half of all the timber lands in the United States. There are twenty-eight hundred billion feet of timber in the United States, while these three States have of this amount thirteen hundred billion feet.

By-product charcoal plants, close to the large lumber operations, should at present not only be the wise policy for lumber operators to follow, but should also give a good revenue from what at present is a decided nuisance and often a menace, and supply the needed charcoal for iron reduction.

It would take many years to develop 1,000,000 tons of charcoal per year on the West coast, but it is interesting to note that under conditions considerably adverse to our own this has been accomplished in Sweden.

Limestone is abundant all through the States, the quality of which is suitable for smelting purposes.

Iron ores of varying qualities, some of the highest purity, and others less pure, are available at many points in California and in adjoining States.

Power close to power sites and in the timbered districts, where charcoal could be cheaply made, is obtainable at prices which will make electric shaft-furnace operations not only successful, but financially profitable.

Norway and Sweden produce small amounts of ferroalloys. The raw materials have to be imported. As an example, chrome ore is brought in from New Zealand.

The raw materials for such industries are right at hand in these States and can be had, in many cases, practically at no cost compared with prices paid for similar raw materials brought into Sweden and Norway.

Norway produces some aluminium from ore, part of which is imported and part is obtained from local deposits.

The Pacific Coast States have a very large supply of practically pure aluminium oxide awaiting treatment in waste piles, the aluminium oxide being a by-product in the potash production from alunite. Utah is one of the States where this by-product is produced.

Sweden produces considerable quantities of sodium and potassium chlorate. The raw materials have to stand heavy freight charges as they are imported from Germany. This is also the case in reference to salt used in the manufacture of caustic soda and bleach.

We are favored here by salt, which is readily available. It may be of some interest to know that a caustic soda and bleach plant is being built on San Francisco Bay.

Potassium chloride is to be had from Searles Lake, we hope at no very distant date. Meanwhile we may be able to get this salt from various waste materials available on the Pacific Coast, which are now being absolutely neglected.

An industry of special interest developed in Sweden is the electric reduction of zinc. Not less than 18,000 hp., producing close to 4000 tons of zinc per annum, are consumed in this industry. Ores containing both lead and silver, as well as zinc, are used in recovering the values.

Many of the ores of the West, which are now deemed practically worthless due to zinc content, could be advantageously treated in the electric furnace on the Pacific Coast.

An industry can never be a success if there is no market for its products.

Sweden and Norway together have a population, as mentioned before, of about 9,000,000 people, and since the greater part is a rural population there is a comparatively small demand for manufactured products. Therefore, foreign markets have been sought for the products of the industries.

There is no part of the globe that is not in some way dependent on products made in Sweden and Norway. This wide market field has been developed through necessity and necessity has forced co-operation. Commercial agencies have been formed in foreign ports through which everything from Swedish lumber, sewing machines to electrochemical products have been sold. The different manufacturers have maintained these sales agencies jointly and consequently the selling cost in foreign countries has been brought down to a minimum for the various products.

The nearby European markets are severely competitive, but they have been entered successfully. This has been possible for two reasons: quality of product and price of product.

Sweden and Norway, the latter especially, have learned the art of handling tramp steamers. Due to this fact freight rates for products reaching foreign markets have been brought to a minimum.

It is equally possible for electrochemical industries, or, in fact, any industry on the Pacific Coast to penetrate foreign markets. We can reach from this point over one-half of the world's population by going West and South. Some of the markets are small, but are bound to grow, and if we miss the present opportunity somebody else will step in and collect the harvest which legitimately belongs to us.

The large electrochemical developments in Norway are financed by international capitalists, involving various complex problems, while here, if the needed capital cannot be procured on the coast, projects may be jointly financed by local as well as Eastern capital. This involves at the most a trip East with none of the complications that go with the use of foreign capital.

The Pacific Coast is endowed with raw materials that may in time revolutionize some of the large industries; take, for example, oil so abundantly present in California.

Doesn't it seem like the intention of fate that large high-grade iron ore deposits, hydroelectric power and oil have been placed side by side? Can't we conjure up a new type of iron-reduction process where the iron is obtained from the ores by means of electric heat combined with the carbon and hydrogen in the oil, as reducing agent? I feel certain that the day will come when the Pacific Coast will be a factor in the iron markets of the world, due to the presence of these three agents.

Norway has about 500,000 and Sweden practically 150,000 hp. utilized in electrochemical and electrometal-

lurgical industries. These have not grown over night. On the contrary, careful and faithful pioneer work had to be done not only in the laboratories, but among the population, and also in the Council Chambers of the nation. An electrochemical atmosphere has been produced; the layman has been brought face to face with it in perusal of his daily paper and gradually the population has grasped the fact that (though the details are perhaps hidden to the layman) electrochemistry is one of those mystic shrines by which, if treated with the correct signs known only to a few, new developments and wealths are produced.

We need an electrochemical atmosphere on the Pacific Coast. Up to the present time gold mining has been the atmosphere. Everybody knows what a placer mine or a gold dredge is; the papers are full of it. The large State universities of the coastal States as well as the daily papers, can assist in bringing this electrochemical atmosphere here.

Without fear of being refuted I will say that the Pacific Coast has more potential wealth in its 11,000,000 hp. of water power, of which 93 per cent goes to waste to-day, than all the gold that ever was mined or is still to be mined in these States.

Sweden and Norway are to-day looked upon as electrochemical centers. The Pacific Coast, I believe, will, within the lifetime of most of us, be looked upon as one of the large electrochemical centers of the world due to our being favored with abundant hydroelectric power and the varied and important raw materials needed in these industries and due to the enterprise of the men of this coast.

Electrochemistry is a young science in its present development compared with other sciences. The electrochemical industries are consequently young men's industries. Therefore, young men are needed, men with the pioneer's optimistic resourcefulness and courage. But this alone is not sufficient; they need a special education which the large universities of this coast are bound to give if they are not already giving it to their students.

With the power, the raw materials and the men the Pacific Coast holds a mighty future in the field of electrochemistry.

Great Western Power Company,
San Francisco, Cal.

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The **Draeger Oxygen Apparatus Co.**, Pittsburgh, Pa., have placed on the market a new pulmotor which is designed type "B." A pamphlet has been issued by the company describing the many advantages of this new type.

**Increase in Japanese Zinc and Aluminium Industries.**—Considerable activity is being manifest in Japan in the zinc and aluminium industries. According to Commerce Reports the recent development of the zinc-refining industry has brought considerable increase in the output of zinc ores. The total output is expected to be more than 10,000 tons per year, as compared with 40,000 tons before the war, when the refining mills were mainly dependent on supplies from Australia. The Japan Aluminium Manufacturing Co., which has recently been floated by Tokyo, Osaka and Nagoya capitalists with capital of 1,000,000 yen ($498,500) is building a factory at Rokuga-mura, a suburb of Nagoya. It is to be completed in the course of July, and operations are to be started in August. The management of the company intends at the start, the Japan Chronicle states, to turn out about 250 tons a year. The Japan Aluminium Co. intends ultimately to increase the capital to 10,000,000 yen ($4,985,000) with the object of turning out 25,000 tons a year, that is, the total quantity needed in Japan.

## The Rate of Driving the Blast Furnace

BY J. E. JOHNSON, JR.

One of the most important items in the control of furnace operation is the rate of driving. This is to say, how much iron we should attempt to make per day from a given furnace which depends, other things being equal, upon the amount of coke we burn and that in turn on the amount of blast we blow per unit of time. The best rate must be determined with reference to two sets of considerations, one technical and the other commercial.

The technical ones are: first, effect upon the regularity of the settling of the charge; second, the effect upon fuel consumption; third, the effect upon the power required for blowing; fourth, the effect upon flue dust lost; fifth, effect on the life of the lining. The commercial ones are: first, the effect upon profit, since other things being equal the annual profit is proportional to the tonnage produced; second, the effect upon costs other than fuel cost, principally labor and overhead, since these costs per ton are, other things being equal, inversely proportional to the output; third, the effect upon the value of the power consumed for blowing. This distinction between technical and commercial considerations is more or less arbitrary since all these considerations are partly one and partly the other, but the distinction is permissible to facilitate the more technical treatment of the subject now, leaving commercial considerations to be discussed in a later chapter.

### Effect on Descent of Charge

The effect of the rate of driving upon the regularity of the descent of the charge is placed first because it is of capital importance and affects every other item. Without regularity of descent of the charge we cannot steadily maintain the production of the most profitable grades of iron, we cannot secure the maximum monthly output, we cannot, above all, secure highest fuel economy, and, finally, without it we cannot keep our flue dust losses within any reasonable limits, when running on fine ore.

Reverting to the article on the physical action of the blast furnace it will be seen that the resistance to the passage of the gas rises as the fourth power of the quantity of blast blown, so that from our pressure chart it can be shown that while a 22 x 90-ft. furnace, blown with 45,000 cu. ft. of wind, requires about 13 lb. blast pressure, the same furnace blown with 55,000 ft. of wind would require about 17½ lb. pressure. As pointed out in that article, these figures are both probably a pound or so low, but this fact only exaggerates the difference.

From the conclusions reached as to the relatively accurate balance between the weight of the charge and the forces supporting it, it will be seen that a change like this of almost 50 per cent in blast pressure might easily result in disturbing the floating equilibrium between weight and resistance, and so result in hanging the charge column or some portion of it lying above a tight zone. This would result in slipping, with all its attendant evils—reduced output, poor and irregular quality, higher fuel consumption, and all the rest—these results, of course, being in some rough degree proportional to the seriousness of the slipping caused.

### The Effect of the Rate of Driving on Fuel Consumption

This is a very complicated matter. In the early nineties, when outputs were on the average less than half of what they are to-day, it was supposed that the maximum rate of driving, consistent with economy, had bee nreached. In the interval which has elapsed since,

we have seen a much more rapid rate of driving accompanied by a much higher fuel consumption, but this has been succeeded in more recent years by a marked reduction in fuel consumption, so that the best of to-day is better than that of any past time, irrespective of the rate of driving.

In order to make an adequate comparison it is necessary to have a measure of the rate of driving. This is quite generally taken as the number of pounds of coke burned per hour per square foot of hearth area, so that if a furnace with a 16-ft. hearth were burning 480 tons of coke per day, that is, 20 tons of 2000 lb., or 40,000 lb. per hour, the area of a 16-ft. circle being 200 sq. ft., the rate of combustion is 200 lb. per square foot per hour.

It is commonly considered that 250 lb. per square foot is about the maximum amount consistent with good work, and this figure is in fair agreement with most practice of to-day, though I have operated furnaces burning over 300 lb. per square foot with excellent results in fuel economy for the given conditions. On the other hand, the large-hearth furnaces with which very economical results have been reached in very recent years are only burning about 40,000 lb. of coke per hour in a 17½-ft. hearth, which is less than 200 lb. per square foot.

It has seemed to me that this basis of comparison was not altogether a correct one. I have endeavored to show in the earlier articles that the real combustion space of the furnace was not a single plane at the tuyeres, but that combustion was going on throughout the bosh, that is, from the tuyere plane to the top of the bosh, and in order to obtain truly comparative figures we would rather use the combustion per cubic foot of this space than per square foot of hearth area. On that basis the large-hearth furnaces are really as hard driven as any, for two reasons: First, while the hearth is very much larger than that of other furnaces with the same height and bosh diameter, by this method of figuring this change affects only the smaller diameter of the frustum of an (inverted) cone whose base is the bosh diameter, so that the percentage of change in its volume produced by this increase in its smaller diameter is less than half that produced in the smaller area itself. Second, the wide-hearth furnace has been accompanied by a lowering of the top of the bosh so that its vertical height is decidedly smaller, and this reduces the volume of this zone of the furnace as much as the widening of the hearth increases it.

It is an unfortunate fact that we have no figures for coke consumption per cubic foot of bosh space, and this unit of measure can therefore only be introduced into general use after a considerable campaign to replace the older but less accurate unit.

Concerning the results of the true rate of combustion upon fuel economy we know much less than we should, but some of the factors which affect it may be pointed out. The first of these is the velocity of the combustion of coke in a blast initially air, but burning progressively to CO and nitrogen. A simple calculation shows that the blast can be but a few seconds in passing from the tuyeres to the top of the bosh. The volume of air blown into the modern furnace is about sufficient to fill it twice a minute if the furnace were empty and the air under atmospheric conditions. As a matter of fact the air is increased in volume between three and four times by heating, and this volume is reduced by the compression under which it enters the furnace, this decreasing, of course, as it rises, so that its average pressure is one and a half times atmospheric, while its absolute temperature at the top of the bosh is six or seven times atmospheric, and the average something like four times atmospheric, hence its actual volume is nearly three times that under atmospheric conditions. This would mean that the furnace, if empty of solid and liquid matter, would be filled six times per minute. But we have seen that if it were filled with uniform spheres the total voids would only be about 25 per cent of the total, and with very irregular material, including much fine, continually settling and thereby reduced to minimum volume, the voids are probably not over a half of this, perhaps much less, so that the voids are probably only about an eighth of the total contents of the furnace. This indicates that the actual gas volume is sufficient to fill the voids at least forty-eight times per minute, so that in about one second the blast which enters at the bottom of the furnace passes through it and is discharged as gas at the top.

Now taking the height from the tuyeres to the top of the bosh as one-eighth or even one-sixth of the total height of the furnace we see that less than one-sixth of a second is available for the complete combustion of the oxygen of the air to CO. Such a velocity makes it impossible that combustion should go on in the interior cells of the coke because it is impossible that the air should penetrate a solid (though porous) structure and make its exit in that time; therefore combustion must proceed only upon the surface of the coke. This is not unlimited, and as we know that an appreciable interval of time is necessary for the complete combustion of air it becomes evident that there is a limit beyond which we cannot drive the furnace and have the combustion completed in the proper zone.

This means that for still faster driving more volume would be necessary to complete the combustion, and, therefore, that this would extend to a higher level in the furnace. All our experience in operation, and all of the chemical and thermal theories set forth in earlier chapters tend to the conclusion that the best work can only be done by keeping the zone of fusion as low as possible. It is impossible to go over all the reasoning which leads to these conclusions here; it is a fact based primarily on experience, and one of the best proofs is that the remarkable work of the wide-hearth furnaces has been built upon and around the principle of keeping the zone fusion as low as possible, and the economy which has been obtained in furnaces in which a low bosh is one of the outstanding features, creates a strong presumption that the lowering of the zone of combustion is at least an important factor in the very economical results obtained.

When furnaces are overblown it is a quite general impression, and I believe an entirely correct one, that the upper zone of combustion rises, in accordance with the above reasoning, and this is accompanied by an increase in fuel consumption. In fact, it must be evident that if the fuel consumption be controlled by the quantity of high temperature heat available, anything which tends to dissipate this limited supply of heat over a wider zone must militate against its concentration, and therefore against fuel economy.

The same reasoning which applies to combustion applies to other reactions which must go on. The reduction of the ore is essentially a task which demands time for its completion in the maximum degree possible in each zone before descending into the next, and as this is the essential condition for the maximum possible oxidation of the gases, on which, as we have seen, the total heat development depends, a sufficient allowance of time for the completest possible reduction of the ore in each zone is an indispensable condition for maximum economy. If the ore descends so rapidly as to reach the hearth without the completest possible reduction, the effect is of the same general kind, but of a much higher

order of intensity. We have in such a case the conditions which led to low fuel economy with the wet ore in the charcoal furnace, described in the article on thermal principles.

So it is with all the other reactions; the decarbonization of the limestone, the complete union of the flux with the impurities of the charge, etc. If sufficient time be not allowed for these we shall pay for it by expending more heat than is absolutely necessary upon bringing about the necessary conditions. On the other hand, we shall see later in the present article that there are heat losses of vast importance which are irrespective of the rate of driving. The furnace is constantly undergoing a loss by radiation and cooling water of some 15 or 20 per cent of its heat, especially of that in the hearth; this is 15 per cent of the total developed when the furnace is running at full speed, which is a convenient measure.

But if the furnace stops, the loss continues at the same rate per hour as long as the zones of the furnace remain at the temperature which they have in operation, so that if the furnace were to be run at 15 per cent of its normal rate we should supply just enough heat to make up for the losses without supplying any for the production of iron; if we ran at 30 per cent of the normal full rate we should, on this basis, lose 50 per cent of the heat produced, and the fuel consumption would accordingly be nearly twice what it is at the normal full rate. If we drive at 45 per cent we lose one-third on the same basis, and so on. The figures used are not intended to be exact, though they are approximate to the best of our knowledge.

This line of reasoning shows that we must not allow any more time for combustion, reduction, etc., than is necessary for those operations. We are not at liberty to increase the economy of the furnace indefinitely by slowing down to obtain more complete reactions, because the purely physical radiation and reduction losses begin to assume an increasingly menacing proportion the slower we run. Obviously, then, if we make some loss by allowing a slightly insufficient time for completest reduction, we may offset it by cutting down the radiation losses in a greater degree. If we were considering only fuel economy, our effort should be to run under the conditions which would make the sum of these two losses the minimum. But we shall see when treating of commercial considerations this is only one factor and sometimes by no means the greatest in the solution of the commercial questions involved, and therefore it would be useless to attempt a solution of the purely technical question involved on so theoretical a basis.

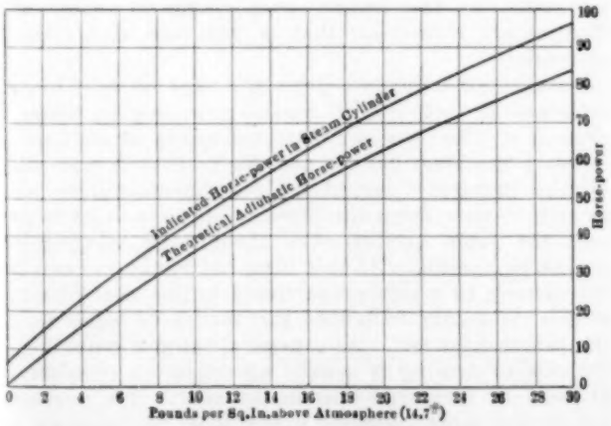


FIG. 1—THEORETICAL AND ACTUAL HORSEPOWERS REQUIRED TO COMPRESS 1000 CUBIC FEET PER MINUTE OF FREE AIR (14.7 LB.) TO DIFFERENT PRESSURES

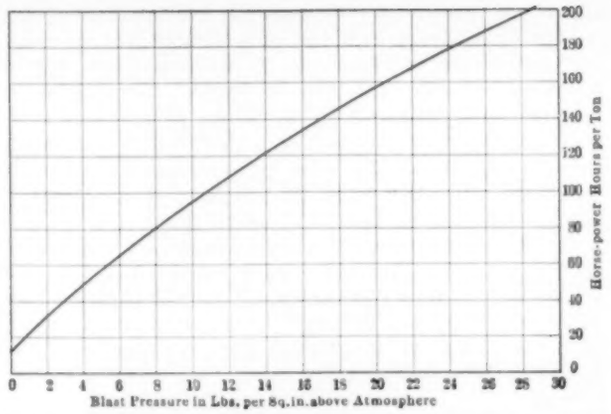


FIG. 2—HORSEPOWER-HOURS PER TON OF IRON PRODUCED REQUIRED TO BLOW FURNACES WITH DIFFERENT BLAST PRESSURES

### The Effect on Power Required for Blowing

This is a subject of the utmost importance from two points of view: first, that of the first cost of the blowing plant; second, that of the consumption of gas required to operate it. The time was when the gas was considered of no use or value, but that time is now long gone by, and it is well understood that the gas represents roughly one-half the value of the fuel, in the best and most convenient form, and in modern plants it is applied to the production of power for uses outside the blast furnace and is an asset of great value. Therefore, it is desirable to use as little of it as possible for the blowing of the furnace itself, since power so spent is a necessary evil and nothing else.

The power required for the compression of a given volume of air to a given pressure varies with the type of apparatus used whether steam engine, gas engine or turbo blower.

More data are available in the case of the steam engine, and I have therefore used it for developing the facts in the following discussion. The lower curve of Fig. 1 shows the theoretical power required to compress adiabatically 1000 cu. ft. of air per minute from atmospheric pressure (14.7 lb. abs.) to different pressures. The upper curve shows the actual indicated power required in the steam cylinders of a blowing engine to compress it to the same pressures with normal assumptions based on practice as to the efficiency of the blowing cylinders and the friction of the engine. By assuming now a figure for the amount of air to burn a pound of coke and the amount of coke consumed per ton of iron we obviously can calculate the horsepower-hours per ton of iron with different blast pressures. The curve of Fig. 2 gives these figures based on normal assumptions for Lake ore practice. But in order to obtain the information that we really need we must go a step further and find the horsepower-hours per ton required with different rates of blowing in a given furnace.

By assuming that the results of the blast pressure chart given in the article on mechanical principles are correct, and combining its results with those just given we may obtain a very fair idea of the horsepower-hours required per ton of iron produced at different rates of blowing. Fig. 3 gives the results of such calculations for a 22.5 x 90-ft. furnace.

It will be seen that the total horsepower required for blowing rises very rapidly, and that the horsepower per ton of product rises at a rate almost exactly proportional to the rate of driving; at 350 tons per day 75 hp.-hr. per ton are required, and at 650 tons 150 hp.-hr. This increase of 75 hp.-hr. per ton represents a real loss,

even if the gas be worth nothing, for the fixed charges on the investment and the operating labor to burn it and utilize the resulting steam are important, however much or little the gas may be worth. Leaving a more extended discussion of these values to a later chapter, we may note that the sum of fixed charges and labor is seldom less than 0.25 cent per horsepower-hour, and therefore the difference in power cost at these two rates of driving is nearly 20 cents per ton.

It may well be reiterated that these are not absolute figures, and that they may vary considerably from the actual figures in a specific case, but that they are based throughout on assumptions in substantial agreement with facts, and it is believed they represent very well the relative power requirements under the given conditions.

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The results will be shown in dealing with commercial considerations.

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With the rapid progress being made in sintering flue dust it seems not impossible that our ideas on the subject of this limitation may experience a considerable change in the near future. The harmful effect of fine ore in the furnace has been explained earlier, and is coming more and more to be admitted, the uselessness if not absolute harmfulness of fine coke is well known; if we can transform these into a highly desirable furnace material without undue expense we may find that the cheapest course is to blow out of the furnace an increased percentage of the objectionable fine materials, put them into a desirable condition and change them back again.

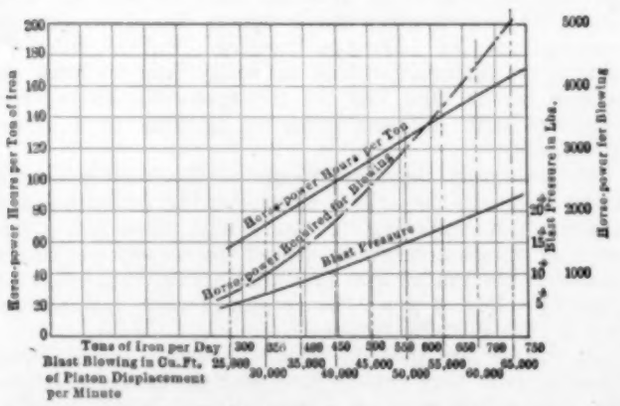
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FIG. 3—BLAST PRESSURE BLOWING POWER AND HORSE-POWER HOURS PER TON REQUIRED AT DIFFERENT RATES OF PRODUCTION WITH A FURNACE 22.5 X 90 FEET

Where lumpy or plastic materials are used the flue dust loss is smaller in proportion to the smaller total quantity of fines present, and this is generally so small that flue dust ceases to be an important fact in the rate of driving under such conditions.

In actual practice we find by experience the rate of driving which suits the general conditions best, and that we regard as the normal which we desire to maintain.

### Spontaneous Increase of Rate of Driving

There often arise conditions under which the maintenance of the best rate of driving is no longer possible. The furnace will sometimes start off and drive at a vastly increased rate without any change in the amount of blast having been made. For many years I did not know the reason for this phenomenon. It was first pointed out to me by A. J. Boynton of Lorain, that this condition arises from the fact that the rate of coke loss by solution or, more accurately, the percentage of the coke dissolved in the upper portion of the furnace, suddenly increases from some change in conditions, perhaps the distribution of the stock or a change in the tightness of the charge, producing a corresponding change in the equilibrium of CO and $CO_2$, with the result that more of the latter is formed at some zone, and this then dissolves more carbon from the coke in order to restore the equilibrium.

Another cause for such change, probably the most frequent one, is increased solubility of the coke due to a difference in oven practice, coal used, structure, or the like, or to a change in the fineness of the ore or its tendency to run down through the charge.

If a furnace working on hard ore were to change from a 10 per cent solution loss to the 22½ per cent solution loss which may occur with all fine ore, it would produce an increased rate in driving of about 15 per cent, and changes as great or even greater than this do at times occur.

The effect of such an automatic increase in driving is usually very objectionable for two reasons: First, it reduces proportionately the time permitted for the complete reduction of the ore; second, and much more important, it corresponds to a reduction of fuel in the hearth and a reduction of hearth heat available, exactly proportional to the increase in the rate of driving. Since, the quantity of blast being constant, the coke to satisfy it must be constant, and if each charge delivers less coke to the hearth proportionately more coke charges are consumed; that is, the rate of driving is increased.

As a result a furnace generally runs off cold in consequence of such a spell unless measures be taken to prevent it. The principal measures available are first, to increase the blast heat if possible so that it may make up the deficiency caused by the extra solution loss; second, to slow down the blowing engines so as to prevent the rapid driving even though the solution loss cannot be checked. If this does not result in reducing the driving to a rate proportional to the blast blown it is then necessary to reduce the burden to make up for the hearth heat lost. As a general thing a reduction in the rate of driving is usually accompanied, temporarily at least, by increased heat in the hearth due, presumably, to the more complete preparation of the stock before its entrance therein, and slowing down the blowing engines is, therefore, the proper procedure if the abnormal rate of driving be long continued.

### Reduced Driving Caused by Furnace Becoming "Too Hot"

We sometimes encounter a phenomenon the exact opposite of that last described. The furnace becomes very hot, the silicon in the iron rises, the actual temperature of the slag and iron rise visibly, and presently the furnace slows down, "won't take the wind," the blast pressure rises decidedly, the rate of driving falls off, and presently the furnace begins to hang and refuses to settle without slacking the blast.

We do not know absolutely the cause of this condition, but as the exact opposite is caused by a sudden increase in solution loss, it is reasonable to suppose that this is caused by a sudden diminution of solution loss bringing an excess of carbon into the hearth.

This would cause the rate of driving to be slowed down in proportion to the increase in carbon delivered to the tuyere zone per unit of time. Increased hearth heat would be developed in the same proportion, part of this would expend itself in reducing more silicon, and the rest would pass out the top of the bosh and carry the pasty zone to a greater height, thereby causing the pressure to rise, and this co-operating with the greater depth of pasty zone would cause a decided increase in the lifting action on the charge column with sticking and hanging as necessary consequences. These are so exactly the results which we see in practice under these conditions that it seems safe to assume that the cause suggested is the true one.

A further confirmation is to be found in the serious after-effect of these conditions which is only too likely to be the scaffolding of the furnace, which is what we should expect from the rise of the pasty zone due to the excess of hearth heat.

After this was written I obtained extraordinary confirmation of its correctness from a chart of pressures at different heights during a "hot stick" furnished me through the kindness of Mr. John N. Reese and his assistant, R. C. Wallace, shown at Fig. 4.

It will be seen that the pressure drop in the bosh and that in shaft are about uniform, whereas in the zone just above the top of the bosh the pressure drop is 6 lb. in 9 ft. where it should be about 1½ lb., so accounting for nearly all the excess pressure in the exact location where we should expect the abnormal sticky zone to be. It is interesting to note that this occurs in the straight section at the top of the bosh; if this were

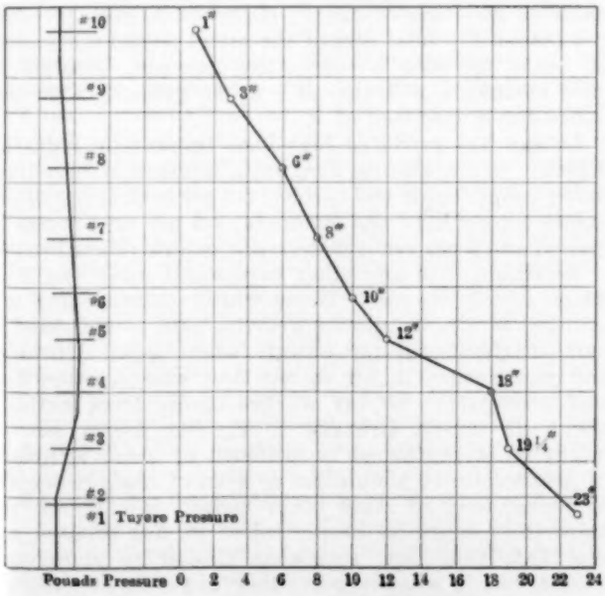


FIG. 4—CURVE OF PRESSURE DROP

absent and the upwardly coverging shaft started directly on top of the bosh it is easy to believe that the sticking would be much worse.

Granting that the cause of this action has been found, what is the remedy? Obviously it is to dissipate the excess heat before it can carry the pasty zone much above the normal level and so prevent the formation at that level of a scaffold due to the adherence of chilled pasty material to the walls when normal temperatures are restored.

This can best be done by "following up" with more blast if the power is at hand to deliver it, for the same reason that we slow down when the furnace is running away. This tends to dissipate the excess heat, or rather to give it less time for action and also to keep the charge in rapid motion and so prevent scaffolding. Unfortunately, the high pressure which accompanies this condition not infrequently limits the quality of wind which can be delivered at the very time we need it most.

In such a case we have no recourse but to cool the furnace off by lowering the temperature of blast to the point required to restore normal conditions. Of course, if the furnace shows a tendency to continue these conditions indefinitely the remedy is an easy and agreeable one, we simply add enough more burden to take care of the excess hearth heat and restore the normal blast temperature, but at the beginning of such a condition a change cannot be brought through quickly enough to prevent bad consequences, so the other remedies must be applied first in any event, for they reach the seat of the trouble instantly.

### The Effect on Life of Lining

It was at one time believed that any rate of driving in excess of a very moderate figure must necessarily result in reducing the length of life of the lining and increasing almost prohibitively the expense and loss of time for relining.

We know now that this is not generally true and that where practice has been good the greatest tonnage per lining is made on steady and unifom but fairly rapid driving.

As a matter of fact, rate of driving is only one, and by no means the most important factor in the life of lining.

The really controlling feature in life of linings is stock distribution. If that be correct we shall be able to drive faster and still have the lining last many times longer than it does with poor distribution; channelling due to the concentration of the lumps on one side of the furnace has destroyed countless linings in a few weeks, but even when this is absent there are frequently conditions due to distribution which destroy a lining quickly. In the next article I shall describe a case in my own experience in which a change of distribution gave a life of lining three times as long as before.

Slow driving may be almost as destructive of linings as excessive driving, for the movement of the change becomes so slow that the whole of the furnaces is not kept in action, a portion of the charge ceases to descend and by long contact adheres to the wall and a scaffold is formed; this causes irregular work and channelling which quickly cuts the lining out, or else the scaffold eventually falls off and brings a quantity of brick with it, this starts a failure of the lining and its end soon comes.

There are other conditions than wear which destroy linings; they disintegrate behind the glazed face which forms on the bricks sometimes in a comparatively short period, three or four years or even less. A lining is just as effectively destroyed by this action as if worn

even if the gas be worth nothing, for the fixed charges on the investment and the operating labor to burn it and utilize the resulting steam are important, however much or little the gas may be worth. Leaving a more extended discussion of these values to a later chapter, we may note that the sum of fixed charges and labor is seldom less than 0.25 cent per horsepower-hour, and therefore the difference in power cost at these two rates of driving is nearly 20 cents per ton.

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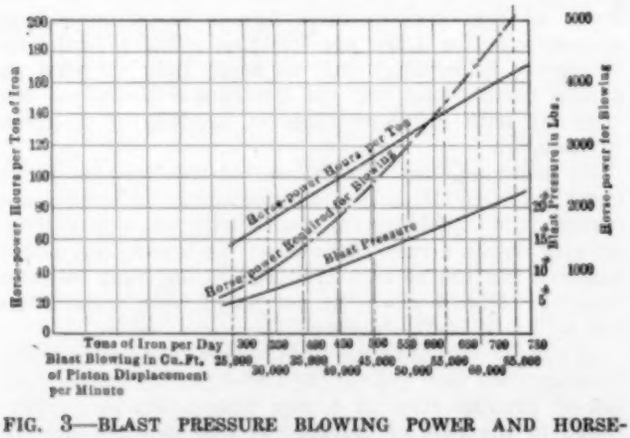
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We sometimes encounter a phenomenon the exact opposite of that last described. The furnace becomes very hot, the silicon in the iron rises, the actual temperature of the slag and iron rise visibly, and presently the furnace slows down, "won't take the wind," the blast pressure rises decidedly, the rate of driving falls off, and presently the furnace begins to hang and refuses to settle without slacking the blast.

We do not know absolutely the cause of this condition, but as the exact opposite is caused by a sudden increase in solution loss, it is reasonable to suppose that this is caused by a sudden diminution of solution loss bringing an excess of carbon into the hearth.

This would cause the rate of driving to be slowed down in proportion to the increase in carbon delivered to the tuyere zone per unit of time. Increased hearth heat would be developed in the same proportion, part of this would expend itself in reducing more silicon, and the rest would pass out the top of the bosh and carry the pasty zone to a greater height, thereby causing the pressure to rise, and this co-operating with the greater depth of pasty zone would cause a decided increase in the lifting action on the charge column with sticking and hanging as necessary consequences. These are so exactly the results which we see in practice under these conditions that it seems safe to assume that the cause suggested is the true one.

A further confirmation is to be found in the serious after-effect of these conditions which is only too likely to be the scaffolding of the furnace, which is what we should expect from the rise of the pasty zone due to the excess of hearth heat.

After this was written I obtained extraordinary confirmation of its correctness from a chart of pressures at different heights during a "hot stick" furnished me through the kindness of Mr. John N. Reese and his assistant, R. C. Wallace, shown at Fig. 4.

It will be seen that the pressure drop in the bosh and that in shaft are about uniform, whereas in the zone just above the top of the bosh the pressure drop is 6 lb. in 9 ft. where it should be about 1½ lb., so accounting for nearly all the excess pressure in the exact location where we should expect the abnormal sticky zone to be. It is interesting to note that this occurs in the straight section at the top of the bosh; if this were absent and the upwardly coverging shaft started directly on top of the bosh it is easy to believe that the sticking would be much worse.

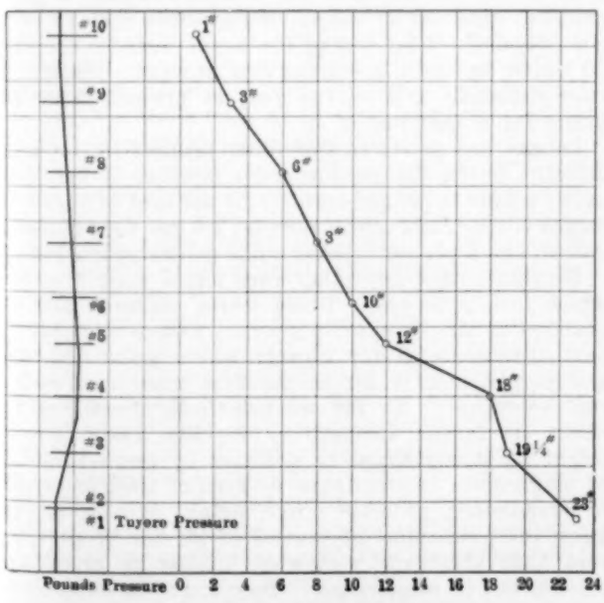


FIG. 4—CURVE OF PRESSURE DROP

Granting that the cause of this action has been found, what is the remedy? Obviously it is to dissipate the excess heat before it can carry the pasty zone much above the normal level and so prevent the formation at that level of a scaffold due to the adherence of chilled pasty material to the walls when normal temperatures are restored.

This can best be done by "following up" with more blast if the power is at hand to deliver it, for the same reason that we slow down when the furnace is running away. This tends to dissipate the excess heat, or rather to give it less time for action and also to keep the charge in rapid motion and so prevent scaffolding. Unfortunately, the high pressure which accompanies this condition not infrequently limits the quality of wind which can be delivered at the very time we need it most.

In such a case we have no recourse but to cool the furnace off by lowering the temperature of blast to the point required to restore normal conditions. Of course, if the furnace shows a tendency to continue these conditions indefinitely the remedy is an easy and agreeable one, we simply add enough more burden to take care of the excess hearth heat and restore the normal blast temperature, but at the beginning of such a condition a change cannot be brought through quickly enough to prevent bad consequences, so the other remedies must be applied first in any event, for they reach the seat of the trouble instantly.

### The Effect on Life of Lining

It was at one time believed that any rate of driving in excess of a very moderate figure must necessarily result in reducing the length of life of the lining and increasing almost prohibitively the expense and loss of time for relining.

We know now that this is not generally true and that where practice has been good the greatest tonnage per lining is made on steady and unifom but fairly rapid driving.

As a matter of fact, rate of driving is only one, and by no means the most important factor in the life of lining.

The really controlling feature in life of linings is stock distribution. If that be correct we shall be able to drive faster and still have the lining last many times longer than it does with poor distribution; channelling due to the concentration of the lumps on one side of the furnace has destroyed countless linings in a few weeks, but even when this is absent there are frequently conditions due to distribution which destroy a lining quickly. In the next article I shall describe a case in my own experience in which a change of distribution gave a life of lining three times as long as before.

Slow driving may be almost as destructive of linings as excessive driving, for the movement of the change becomes so slow that the whole of the furnaces is not kept in action, a portion of the charge ceases to descend and by long contact adheres to the wall and a scaffold is formed; this causes irregular work and channelling which quickly cuts the lining out, or else the scaffold eventually falls off and brings a quantity of brick with it, this starts a failure of the lining and its end soon comes.

There are other conditions than wear which destroy linings; they disintegrate behind the glazed face which forms on the bricks sometimes in a comparatively short period, three or four years or even less. A lining is just as effectively destroyed by this action as if worn

out, and therefore might better have been worn out so as to obtain maximum production from it.

Speaking broadly then, we may say that while the rate of driving is one factor in the life of linings, it is such a small one, with proper conditions in other respects, that we may disregard lining cost in determining the best rate of driving.

From all that has been said as to changes in the height of the pasty zone, the danger of scaffolding they cause, etc., we may see some of the reasons for one of the best established facts of practice, that the best work can only be done over a long period by determining the best rate of driving and adhering to it rigidly except when corrective measures are needed temporarily. The furnaces which have in the long run made the best showing technically and have made the most money for their owners are run on that principle.

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## The Metallurgy of the Rarer Metals*

BY JOSEPH W. RICHARDS

There are many metals which may be called "the rarer metals." Among them the most interesting by far, to the metallurgist and to the economist, are those metals whose compounds are relatively cheap but which command a high price because of the difficulty of their reduction. These are the metals whose market price may at some time be reduced one-half, three-quarters, perhaps nine-tenths, by improved methods of reduction, and the discussion of how this might be accomplished and to what uses these metals at such low prices might be put, is interesting to the border of fascination.

If this article were being written thirty years ago, aluminium would be one of the metals to be discussed. It is now out of that class, but in 1886 it was one of the rarer metals, selling at $10 per pound, although its ores were "as common as dirt." At that time you could buy a ton of bauxite ore containing 6/10 ton of alumina or 3/10 ton of aluminium, for $5, while the 3/10 ton of aluminium was being sold for $3,000, at wholesale. Or, eliminating the purely chemical work, 6/10 ton of chemically purified alumina could then have been bought for $50, while the aluminium it contained was worth on the market sixty times that amount. Such were the metallurgical conditions in the aluminium industry thirty years ago, and so attractive were they to experimenters and inventors that the genius of the profession expended its best talents on the problem, with the result, in less than ten years, of reducing the market price to less than one-tenth its former figure.

The silicon industry furnishes another example in point. Silica is the most abundant and cheapest material in nature, yet silicon was selling in 1900 as a chemical curiosity at *over* $100 *an ounce*. Imagine the stirring up which my metallurgical wits received, when in 1902, Mr. Tone, at Niagara Falls, showed me a barrel full, 100 lb. perhaps, of silicon made in his electric furnace, and asked me what uses it could be put to. At the present time, 10 cents per pound is a good market price for silicon, which is often sold by the carload.

It is such seeming fairy tales as these which constitute the fascination of those metals which are abundant in nature but whose high cost rests on the difficult and costly methods of reduction employed. Such opportunities exist, for our rising generation of chemists and metallurgists to make themselves famous and, incidentally, rich—but they will find their fame more of a reward than their riches.

Among the metals at present of high price, but which by improved metallurgical processes might be made very cheaply, are beryllium, boron, magnesium, calcium, strontium, zirconium, molybdenum, barium, titanium, chromium and cerium (mixed metals of the cerium group).

### Beryllium

Commencing with one of the light, alkaline-earth metals, its ore is not as rare as is ordinarily supposed. Most non-mineralogists link it with beryl, and think of the latter as a very pretty and very expensive gem—the emerald. But the emerald is only the clear green or aquamarine stone, while massive beryl, looking like massive green quartz, is much more common, and is even abundant in some localities. The beryl crystals of Acworth, N. H., are sometimes as large as a barrel, and the massive beryl at this locality is quarried like feldspar. Its composition is

| | |
|---|---|
| $SiO_2$ | 67.0 per cent |
| $Al_2O_3$ | 19.0 per cent |
| BeO | 14.0 per cent |

It is difficult to say what the price of this material would be if it was desired by the ton, but it should not be expensive. When chemically treated, both the $Al_2O_3$ and the BeO which it contains could be separately obtained.

Up to the present, no one has succeeded in isolating the metal except by reducing a halide salt of beryllium by potassium or sodium (Bussy, Wöhler, Debray, Menier, Reynolds, Nilson and Petterson, Kruss and Moraht) or by electrolysis of double chloride, bromide, or fluoride of beryllium and sodium or ammonium (Borchers, Warren, Lebeau, Liebmann).

These methods are tedious and costly for two reasons: first, they require the conversion of the beryllium into an anhydrous halide salt, which is a difficult chemical operation, and, second, the electrolysis sets free the halogen, which is very destructive of electrodes and apparatus. It is not to be expected that beryllium can be made cheaply until someone masters the direct electrolysis of the oxide, dissolved or suspended in a more stable melted salt. This is by no means an impossibility; a similar solution was found for the aluminium problem, and systematic, determined search would in all probability find the answer for beryllium. In such a case, the cost of the metal would depend only on the cost of beryllium oxide, being probably not more than 20 cents per pound plus the cost of the oxide. Since BeO is only 36 per cent Be, it would require 3 lb. of oxide to give one of metal; if the oxide cost 10 cents per pound, the total cost of the metal should not exceed 50 cents, by such a supposition process. Dealers in rare chemicals will charge you, at present, $300 per ounce for a specimen of it.

Lebeau has produced beryllium bronzes by reducing directly, in the electric furnace, a mixture of beryllium oxide, copper oxide and carbon; 0.5 per cent of beryllium makes copper hard and sonorous; 1.5 per cent makes it yellow, and 5 per cent makes a fine golden yellow bronze.

Beryllium, like any other rare metal must find uses which justify its cost. Being white, malleable and unchanged in air, its specific gravity, 1.64, would make it particularly useful for objects where great lightness and permanence in air is the first consideration and cost secondary. So far we practically know nothing about its tensile strength or rigidity, about how it might be strengthened or stiffened by small additions of magnesium or aluminium or even of zinc, or copper, or manganese, or some other metal. We do not yet know the mechanical properties of its fine bronzes, except that they are somewhat similar to aluminium bronze, but in what respects they might be superior or perhaps unique is unknown. Finally the metal may

*A paper read at the Cleveland meeting of the American Institute of Chemical Engineers on June 14, 1916.

easily possess special properties, now unknown, which may render it particularly useful for some specific purpose. Its specific heat, for instance, is the highest of any useful metal, and its latent heat of fusion must be abnormally high, possibly 300 calories, and its latent heat of vaporization probably higher than that of any known element except carbon or boron. Such characteristics might give it special uses in electrical instruments, or for physical apparatus, where its cost would not exclude its use. Altogether, beryllium is a metal which will well repay extended metallurgical research and minute physical and chemical study of its many unique properties.

### Magnesium

The metallurgist has been coquetting with magnesium for half a century, and has, as yet, not made a fraction of the progress which he should have made. We can get its oxide cheaply and in abundance, its salts are not very difficult to prepare, we know their properties to a considerable extent, we know almost all the properties of the metal which bear on its isolation, and yet the industry lags and halts as if there were no such thing as modern metallurgy. To prepare by tedious methods the anhydrous double chloride, and then to electrolyze it about as Matthiesen did fifty years ago, is nearly all that can be said with certainty about its present metallurgy. At any rate, using magnesium oxide costing a few cents per pound, the metal sells for about as many dollars per pound, and yet there is a great scarcity of the metal.

Dr. W. M. Grosvenor, in a recent paper before the American Electrochemical Society, summarizes the present methods of production and the uses of the metal. Happily he also suggests the great field open for improvement, especially for radically new metallurgical methods of production. With magnesium in its salts costing less than 8 cents per pound, he places the actual cost of the metal at $1 per pound, leaving over 90 cents per pound for the cost of its extraction. "Brethren, these things ought not so to be." Speaking with the enthusiasm born of past achievements in electrometallurgy, along entirely analogous lines, a modern, up-to-date attack on this problem ought to result in producing magnesium at 25 cents per pound.

The point of attack should be undoubtedly to reduce the oxide directly. The halogen salts are hygroscopic, and the halogen is destructive of the reducing apparatus. It is almost certain that proper research will enable the electrometallurgist to feed MgO directly into an electrolytic bath of fused salts and take magnesium or magnesium alloy from it. The pure metal will float on almost any fused salt, but its alloy with heavier metals may be made such as to sink, and many of its alloys have immediate useful applications.

Dr. Grosvenor makes suggestive remarks about the reduction of magnesia by carbon. If the boiling point is only 1200 deg. C., then a process of reduction similar to that of zinc oxide might be practicable if we could (1) find a retort material which will stand the temperature required (1800 deg. to 2000 deg. C.), and (2) condense the vapors without contact with air. Fortunately, magnesium does not form carbide at high temperatures, so that its reduction is simpler by that much. Dr. Grosvenor speaks of a chemical process which will use cheap raw material, a moderate amount of fuel, and give a fair efficiency of reduction. With all expenses added, he estimates a cost not over 35 cents per pound. This may be true, but whether it materializes or not, he and his colleagues have the right vision of the possibilities, I may even call them the probabilities, of this field; they are truly "absolutely fascinating."

While the world-war lasts, with its enormous demand for magnesium for military purposes, the price will remain in the dollars per pound. But experience in this line is being rapidly accumulated, and improvements are undoubtedly rapidly succeeding each other, although keen competition is keeping them secret as far as possible. After the war's close, with normal industrial conditions reappearing, magnesium will undoubtedly sell at a price which will take it out of the class of the rarer metals and put it among the common ones. As the price goes down its industrial uses will increase in a geometric proportion, and instead of production being expressed in thousands of pounds per year it will reach thousands of tons. This will be another of the by-products of the great war's stimulus to metallurgical industry.

The possibilities held out to the metal industry by reasonably cheap magnesium are extremely interesting. The stiffening of magnesium to produce strong alloys with specific gravity not over 2 has not been properly studied. It is quite possible that alloys analogous to *duralumin* may be discovered, as strong as soft steel and only 30 per cent of its weight, which will find extensive use in aeroplanes and dirigibles. Such alloys may also largely displace aluminium alloys, which are used by thousands of tons annually in the automobile industry, with a saving of one-third in weight, which will compensate for a higher first cost. The metallurgical uses of magnesium will also be greatly extended by its lower price, such as for deoxidizing brass, bronze, nickel, monel metal, since it is a much stronger deoxidizer than aluminium. In fact, aluminium has blazed the way into numerous uses for which magnesium, as soon as it becomes cheaper, will compete and replace its older sister. With supplies of magnesium ore as plentiful as those of aluminium ore, and the metallurgist awake to his responsibilities and producing the metal cheaply, there will inevitably be a large future for magnesium as one of the common metals of every-day life.

### Calcium, Strontium, Barium

These are a trio of highly interesting elements, common enough in nature, but all scarce and of high price because of the metallurgist's lack of efficient and cheap methods of reduction. With burnt lime, CaO, one of the cheapest of common materials, strontium sulphate, a mineral found in considerable abundance, and barium sulphate, so common, as heavy-spar, that it is used as an adulterant for some cheap paints, the metallurgist is again faced with the demand for cheap methods of reduction. And yet, although calcium is sold at a few dollars a pound, strontium and barium cost several dollars per ounce. Here is a twofold need: first, cheap production; second, a thorough study of these metals to find out their specific properties and their particular uses. Which should be undertaken first is an interesting topic for discussion. Historically, the metallurgist has usually produced the metal first and then studied its properties and possibilities; at present, with these metals already at hand, metallurgical activity might be greatly stimulated by extensive studies of the properties, alloys, and chemical uses of these elements. Our present information in this direction is fragmentary and partly unreliable as far as it goes. A Carnegie Research scholar, or even the Bureau of Standards, by disclosing to us some of the unknown properties of these elements, might stimulate the experimenter to renewed efforts to find cheaper methods of reduction.

**Calcium,** at the present time, is the best known of these three elements. The method of electrolyzing its fused chloride and lifting the metal away from the surface, as an irregular stick, has been fairly successful, and since the chloride is not difficult to dehydrate, the whole operation is not very expensive. Calcium is there-

fore, at present, perhaps a semi-rare metal, which could be produced much cheaper even by present methods if made on a large scale to fill a large demand. The method of production is easily susceptible of minor improvements, and the chlorine is a valuable by-product to the manufacture. The principal hitch at present is in finding the uses for a large production of calcium. Here is where extensive study of the properties and possible uses of calcium would greatly stimulate the metallurgical industry. With specific gravity of 1.85, its possible alloys with other light metals should be exhaustively studied; quite possibly some of them are strong, resistant to air and water, perhaps even to acids. Calcium tarnishes easily in the air, and magnesium also, but it is quite possible that some alloy of the two does not tarnish, and may have valuable mechanical properties. Another large possible use is as a chemical purifying agent in melting and casting metals. Calcium-silicon-aluminium alloy has already found application as a deoxidizing agent in steel, because while aluminium oxide and silicon oxide and their combination with each other are infusible at steel-melting temperature, and therefore are eliminated slowly from the metal, calcium oxide forms with these an easily fusible slag, which easily rises out of the molten metal. It is quite possible that a small addition of metallic calcium may in a similar manner reduce the amount of sulphur and phosphorus in steel, because it is either as calcium sulphide or calcium phosphate that these elements are eliminated in refining steel. Other metals and alloys whose properties are damaged by sulphur or phosphorus may be similarly refined or improved. The alloys of calcium with copper, tin, bronze, brass, monel metal, and other commercial alloys have not been studied; until they are, no one knows how many useful mixtures may exist with particular properties of industrial value. The question of adding calcium to the light stiff aluminium alloys, for instance, is worthy of attention, but has not been touched.

**Strontium** is a silvery-white, very soft metal, with properties similar to calcium, density 2.54. Its ores cannot be called rare minerals, and it is a rare metal, therefore, only because of the difficulty of its isolation. It is chemically very active, and electrochemically extremely hard to manage. It has about the same specific gravity as its fused salts, so that it neither rises nor sinks in any of them quickly; it seems also to redissolve in its melted salts with great velocity, so that very high current density is required to obtain any metal at all. Its surface tension appears to be abnormally high, so that it separates out in more or less minute globules which are highly indisposed to running together into one mass. What an attractive subject this forms to the electrochemist who really wants to meet difficulties and taste the joys of overcoming them. And then one may well ask: To what purpose? Here, again, we do not know, but we can feel confident that in the innumerable list of possible combinations of metals strontium might have properties different from any other element, which would lead to its employment on a large scale. These are all questions of the future which form the undiscovered country open to the investigator and chemical pioneer. We may well thank our stars that the world of science still holds unexplored areas to tempt the adventurous investigator and to reward the *Wanderlust* of the metallurgical pioneer.

**Barium** is common in its compounds and almost unknown in itself. Under electrolytic conditions where calcium comes out *en masse*, and strontium separates as small globules, barium is obtained only as a fine powder. Its density is 3.75, but its salts are heavier than the corresponding strontium and calcium salts, so that the fine powder may sink or swim, largely according to the temperature. And yet the fused barium salts are very decent and manageable salts, easily obtained anhydrous and melting cleanly. Their electrolysis, however, is nearly the most difficult task that the electrometallurgist can take up. But it should be taken up and mastered, because a metal so common in its compounds could be obtained in large quantities if uses for it were developed, and if our modern electrometallurgists are worthy successors of Faraday, Bunsen and Castner, they should vigorously attack the problem of its cheap extraction. Even if their end was not reached, they would be whetting their metallurgical wits upon the finest of chemical whetstones, and their experiences would be of value to themselves as well as to other lines of electrometallurgy.

### Boron

As an intermediate element, semi-metal, cheap and abundant in its compounds, yet almost unknown as an element, boron is very interesting. Although quoted at several dollars an ounce, yet there are possibilities of it being made for $x$ cents per pound, where $x$ may be anything over 25. It is only the prophetic prescience of the enthusiastic metallurgist, however, that can discern this goal in the distant future.

Boron occurs in nature as its oxide, sassolite, containing 31 per cent of boron; as borax, containing 11.5 per cent of boron, and as colemanite, containing 18.9 per cent of the metal. These sources are comparatively abundant, the oxide being found in volcanic districts, borax near dried-up lakes, and colemanite (calcium borate) being literally a waste product of the borax mining for which no use has yet developed.

Gay-Lussac and Thenard, Wöhler and Sainte-Claire Deville reduced the oxide by potassium or sodium, other chemists by phosphorus, magnesium, aluminium and calcium, while Duncan reduced boron chloride gas by hydrogen. Chemically, its reduction does not appear to be of extraordinary difficulty. Electrochemically, Davy electrolyzed fused boracic acid, Gores potassium borofluoride, and Faraday fused borax. All describe having isolated boron. Quite recently, Weintraub has decomposed boron chloride by hydrogen in a high-tension arc, and obtained purer boron and in larger quantity than any previous investigator. His classical paper is in the *Transactions* of the American Electrochemical Society (1909) 16, 165.

The properties of the pure boron obtained by Dr. Weintraub are exceedingly interesting. Its fusing point is extremely high, between 2000 deg. and 2500 deg. C.; it was fused in a boron nitride crucible under the pressure of its own vapor. Its boiling point is near to its fusing point; it has considerable vapor tension as low as 1600 deg. C. It has a conchoidal fracture, and is nearly as hard as the diamond. At room temperature it is electrically almost a non-conductor, but at 500 deg. C. its conductivity has increased 2,000,000 times; at 1000 deg. C. its conductivity is of the order of that of the metals. Applying moderate voltages to a cold piece, it soon warms up and makes itself a good conductor. Such extraordinary properties suggest its use for many interesting electrical contrivances, which are enumerated by Dr. Weintraub.

Other uses of boron, which have not yet been thoroughly investigated, are in the formation of boron steels and boronized copper. The former were investigated by Guillet, in France, with irregular results; in some respects, at times, the effects were similar to that of vanadium in the famous vanadium steels, at other times the results were different. The uncertainty may have been due to irregular composition of the ferro-boron alloy used. A great amount of investigation should be

done on this line, first in making a reliable quality of ferro-boron, and second in using it systematically in various qualities of steel. The question of boronized copper is in a still greater state of uncertainty. Boron or even boron sub-oxide ($B_2O$, or, perhaps, boron saturated with $B_2O_3$) added to melted copper enables a perfect copper casting to be obtained of practically 100 per cent electrical conductivity; a trade product sold as boronized copper has similar effects in producing sound copper castings. These results are only the beginning of an extensive field of investigation of the effects of small amounts of boron on metals and metallic alloys. They will certainly lead to important metallurgical discoveries and improvements.

In metals and alloys boron can act chemically as a purifying or refining agent to remove oxygen, nitrogen, and perhaps sulphur, phosphorus, and dissolved oxides, while in larger amount it acts metallurgically as an alloying element. In the latter respect it forms true alloys, such as the ferro-boron alloy, which is an article of commerce. The possibilities of extensive use in molten metals and alloys are great, but mainly dependent upon systematic metallurgical research in properly equipped laboratories.

The production of the metal and its alloys also needs expert attention. For use in steel, a good uniform quality of ferro-boron is needed, and the manufacture of this in satisfactory uniform quality has not yet been mastered. Some years ago, the Pacific Coast Borax Company offered a prize of $500, to be awarded by the American Electrochemical Society, for a practical electric furnace method of producing ferro-boron directly from calcium borate (colemanite), a waste product of the borax mines. A few years later the prize money was returned by the society to the company as not having been earned, although several attempts were made at it. For use in copper, brass and bronze, a cuproboron alloy answers as well as having pure boron. One method of making this is being tried, and the product is giving some very satisfactory results. Improved and more certain means of getting boron into copper are needed, and could probably be found by a moderate amount of careful investigation. As for pure boron, and the fascinating possibilities dependent on its remarkable properties, Dr. Weintraub's method makes the product, but at considerable expense, and a cheaper, easier method is a great desideratum. If such is found, boron will certainly occupy an important place among the useful metals.

### Chromium

This element is also common and abundant in nature, and rare and expensive as a metal. Chromite, containing 34 per cent of chromium, costs normally $20 to $25 per ton, while the ferro-chromium alloy produced from it sells at $100 to $550 per ton, according to the per cent of chromium and carbon contained. But pure chromium, carbon-free, is produced only by reduction of chromium oxide by aluminium, and commands 75 cents per pound. The use of chromium in steel is rapidly extending to all varieties of extra hard and high-speed steel, but the use of pure chromium is limited by the high cost of its production and our lack of knowledge of how to handle it and of its possible useful effects. For example, chromium electroplating is white and durable, and for many purposes may be superior to nickel and almost equal to platinum plating, but the technique of always getting perfect plating has not been satisfactorily mastered. Cobalt-chromium alloys have been made which have some of the remarkable properties and uses of high-speed tool steel (stellite alloy of Mr. Haines). This is an excellent example of totally unexpected and valuable physical properties being discovered by systematic investigation. These alloys, however, must be made from pure chromium and not from ferro-alloy. How many other remarkable alloys yet remain to be discovered by patient and intelligent investigation no one knows or can even guess.

As for the methods of reduction, ferro-chromium alloy carrying high carbon (6-8 per cent) is produced quite cheaply in crucibles, cupola furnaces, blast furnaces, or electric furnaces. Low-carbon ferro-chromium commands three to five times as high a price, because of the difficulty of decarbonizing the raw product. It is very much to be hoped that tests will be made in the electric shaft furnace to see if it is not possible to produce directly from the ore a low-carbon product. The thing has been done in the case of pig iron, producing a low-carbon product which is called pig steel; there is no inherent impossibility in similarly mastering the conditions for producing directly the low-carbon ferro-chromium. The present prices of the two products, $100 and $500 per ton respectively, would warrant great efforts in that direction.

Similarly, chromium is not a difficult metal to reduce to the metallic state, but it is a difficult question to find the proper flux and to keep carbon out of it. Goldschmidt reduces it by aluminium; electrolysis of its fused salts is difficult because of their high melting points. If electrolysis of aqueous solutions of chromium salts could be satisfactorily controlled, so as to produce heavy deposits, this might open the door at once to cheap and pure chromium. Electrolysis of molten relatively fixed salts in which chromium oxides are dissolved (similar to the Hall aluminium bath) is not a hopeless proposition. The chromium would be plated solid, however, on chromium cathodes, since the working temperature would be below the melting point of chromium.

The metallurgy of chromium is full of attractive possibilities, and the usefulness of pure chromium in the field of alloys is only beginning to be scratched; the scratching, however, is proving very much "worth while."

### Titanium

Our friend Mr. A. J. Rossi and the Titanium Alloys Manufacturing Company of Niagara Falls are the *alpha* and *omega* of the titanium industry. Nearly fifteen years ago my first introduction to Mr. Rossi was in the historic barn at Niagara, the cradle of so many of the Niagara Falls industries. Mr. Rossi was running the electric furnace and Mrs. Rossi was in the little laboratory making the necessary analyses.

Everyone knows of the enormous masses of titanic iron ore in northern New York and Canada, which contains so much iron and so little sulphur and phosphorus, that every blast furnace would be glad to get it if it was not for the titanic oxide, which makes it so unworkable that you could not give it away to them. Mr. Rossi tried first to extract the iron only, throwing away the titanium in the slag, but that was not profitable. He then turned to producing ferro-titanium alloy for use in steel and cast iron, and by indomitable perseverance has made that a success. A finely written booklet of over 100 pages, published by his company and to be had for the asking, tells the whole story, so why take up time to rehearse it here? Get the booklet and read it.

In addition to titanium treatment of steel, to deoxidize and denitrogenize, this company also makes a specialty of titanium-treated aluminium bronze, also of titanium-treated bronzes and brasses of various compositions.

With titanic iron ore carrying 10 to 15 per cent of titanium as cheap as iron ore, and if iron-free material is required, rutile, 60 per cent titanium, at 5 to 7 cents per pound, there is no lack of cheap raw material. If

uses are found for pure titanium, however, some other than the electric furnace must be used to reduce it, because, in absence of iron, titanium carbide would result. The methods for producing pure titanium are, like its prospective uses, still in the future, but they nevertheless are worth study and work. One can buy titanium metal now at about the price of silver, but if the problem were properly faced it could probably be made as cheaply as chromium.

### Molybdenum

Molybdenum sulphide, $MoS_2$, 60 per cent molybdenum, looks almost exactly like graphite, and is about as widely distributed. Normally, it can be purchased as 90 per cent concentrates at 25 cents per pound. This would make the raw material for 1 lb. of molybdenum cost nearly 50 cents; the selling price of the metal is about $2. This leaves a large margin to pay for reduction. In fact, $1 per pound of contained molybdenum ought to return the reduction works a good profit.

However, the principal need of the molybdenum industry is a better utilization of its sources of raw material. The deposits have not been, in general, properly prospected or opened up, and then not properly worked. They are usually low-grade propostions, with 5 to 10 per cent of molybdenite disseminated through hard rock. This calls for careful study of crushing and concentrating methods, so as to minimize waste and loss. In most cases, the actual treatment falls far short of this, and possibly half the molybdenite in the ore is lost. The producers of the concentrates are being paid high prices for their material, but the market is limited and dull. If molybdenite were sold cheaper, there is little doubt that ferro-molybdenum, 50 to 85 per cent molybdenum, could be sold at half its present price, and the uses of molybdenum in steel correspondingly increased. New uses have also been found, such as the molybdenum wire so useful in electric resistance furnaces. This wire is scientifically very useful in that it resists the alloying action of many liquid metals even at very high temperatures. Dr. C. G. Fink of the Edison Lamp Works has studied these notable physical and chemical properties, and has described them in the *Transactions* of the American Electrochemical Society (Vol. XVII, page 229, 1910).

### Zirconium

We may mention this element, which, as metal, is rare enough, but whose oxide has recently been found in considerable abundance. The familiar mineral zircon is the silicate, containing nearly 50 per cent of zirconium, but it is found only in limited amount. In the last ten years the oxide, baddeleyite, has been found in large quantities in Minas Geraes, Brazil, running 75 to 95 per cent pure, giving 50 to 75 per cent of the metal. This source is now so common that it sells at 4 to 5 cents per pound, and is being used in large quantities as a refractory material, on account of its high melting point (2000 deg. C.), high resistance to all kinds of slags, low thermal conductivity and low coefficient of expansion.

The metal, however, is almost an unknown quantity. It has been obtained by the action of potassium or sodium on the anhydrous fluorides. Fused, it is white, density 6.4, melting point 1500 deg. C., hard enough to scratch quartz. Ferro-zirconium has been made in the electric furnace and used in small amounts in steel with rather indefinite results. And yet, if some very useful proportions of zirconium were discovered, the metal could undoubtedly be prepared at a reasonable price—only a fraction of the $5 per ounce now asked for it as a chemical curiosity. How it is to be obtained cheaply is one more of the interesting questions confronting the metallurgical pioneer.

### Cerium

There is a peculiar interest attaching to this metal and its close associates, from the fact that hundreds of tons of fairly rich cerium material is lying on the waste heaps outside of the incandescent mantle factories. The thorium ore used by these factories is monazite—a phosphate of the cerium earths plus thorium silicate. On extracting the thoria, the residue is worthless for mantle fabrication. It is known as "commercial cerium carbonate," and contains cerium, lanthanum, neodymium, praesodymium, samarium, gadolinium, yttrium, ytterbium, a little thorium, and considerable alkalies, iron, phosphoric acid and silica. By treatment with acids, precipitation of the rare earths, and ignition, a chocolate-brown mixture of oxides of the rare earths is obtained, in which cerium oxide predominates, and which contains nearly 50 per cent of metallic cerium. When this mixture is reduced directly, without further separation, to the metallic state, an alloy of the rare earth metals is obtained which is known as mixed metal (mischmetal) or impure or commercial cerium. The composition of mischmetal naturally varies, but may be taken as approximately 30 to 50 per cent of cerium, 15 to 25 per cent of lanthanum, 10 to 15 per cent of the didymiums, up to 20 per cent of the yttrium metals, and 1 to 5 per cent of thorium.

An immense amount of laboratory and practical work has been expended on the production of mixed metal and of purer cerium. Professor Muthmann and his students in Munich and Alcan Hirsch in the United States deserve particular mention for their articles, in *Liebig's Annalen* (1902 to 1910) and *Transactions* American Electrochemical Society (1911) 20, pp. 1-102, respectively. Dr. Auer von Welsbach was the pioneer in the commercial manufacture and use of mischmetal. Annoyed by the sight of heaps of the cerium residues around his mantle factories, he experimented with their reduction to mischmetal and with the possible uses of the latter. Finding that it gave off sparks when scratched he conceived the idea of using it in automatic lighters, but found that it sparked far too feebly and unreliably to be practical. He then thought that if he purified the cerium it might give sparks more freely, but on making the purest cerium he found it to spark less than the impure metal. Turning in the opposite direction, he took mischmetal and added to it alloying metals not of the rare earth class, and found that they increased the sparking property. Iron, for instance, when increased to 30 per cent gave an alloy with remarkable spark-giving properties, such as make it most efficient and reliable in automatic lighters. This has formed the basis of the 'pyrophoric alloy' industry, since although other metals have similar effects the 30 per cent iron alloy is probably the best sparking alloy, for general use, so far made.

The electrolysis of fused cerium salts, double chlorides or double fluorides, to give the melted mixed metal is carried on on a large scale in Austria at Treibach, in Germany near Berlin, and was commenced in the United States, in 1916, near New York City, by Mr. Hirsch and his associates. The technique is not easy to master, and all the works keep their operations as secret as possible. The principal difficulties are the resolution of deposited metal, metal fog, and scattering of the metal as fine globules or "metal-mush" through the electrolyte, making it difficult to unite the metal to one melted mass. Since the latter trouble is largely due to surface tension, a study of this property, particularly how it can be diminished, might help in overcoming the difficulty. As an example of the opposite effect, the

cupelling of lead on a bone-ash muffle depends absolutely, for its success, on the surface tension of the molten lead. But, metallic tellurium, in quite small percentage, *decreases* the surface tension of the lead so greatly that the metal *wets* the cupel and cupellation is rendered impossible. Arsenic, on the other hand, *increases*, the surface tension of melted lead, and is therefore purposely added to it, about 0.25 per cent of it, to lead being made into lead shot, in order to make rounder shot.

A physical investigation of such effects on cerium might well assist in overcoming the scattering of the metal in globules in the electrolyte. Another direction in which improvement might be made would be the careful study of the eutectics of mixtures of cerium salts with barium salts, so as to find an electrolyte of lower melting point in which the losses by re-solution of deposited metal would be less than they are at present. Another possible improvement would be the finding of an electrolyte which would dissolve cerium oxide or the mixed oxides directly, and give metal by electrolysis. Such a bath has been discovered for aluminium oxide, and a long experimental search for a similar bath for the cerium oxides would be amply justified.

The possibility of using the 30 per cent iron alloy as a melted cathode, and enriching it in cerium by electrolysis, might be considered. If we had the fusing point curve of cerium-iron alloys we could draw some useful conclusions in this direction. The addition of small amounts of other metals to the bath, so as to produce other useful cerium alloys directly, might facilitate the electrolytic operation. Further experience with the process, particularly by those familiar with the electrolysis of molten baths for sodium, magnesium or aluminium, will very probably lead to considerable improvements and reductions of cost.

The uses of cerium and particularly of its alloys is sure to increase, and may attain considerable proportions. It has been proposed by Borchers as an addition in small quantity to aluminium, to improve its properties. But the large use will always be the pyrophoric alloys, which have so largely replaced matches. Before the European war, over 3000 workers were employed in Austria in this industry of pyrophoric alloys and automatic lighters. Mistakes were made in the early days of the industry, and some alloys put into lighters which crumbled to pieces by the time the apparatus reached Australia, but continual improvement was being made, until a satisfactory substitute for matches was attained. The improvement most needed in the pocket lighting apparatus is to be able to dispense with alcohol or similar liquid; a wick impregnated with a *solid* combustible which can be ignited by a pyrophoric alloy, would give a great impetus to this art.

The author apologizes for making this paper so largely critical and prophetic. If it has sounded too prospective in tone, the excuse must be that it is inherent in the subject. Some of these elements are among the most common in nature, yet they remain so rare in practical life that they are still chemical curiosities. But the chemical curiosities of one age have frequently become the chemical commonplaces of the next age, and even within a generation some of us have seen this happen, under our own eyes. Let us then be foresighted, forehanded, and anticipate possible developments a little by such a general review as has just been given, so that when some wonderful changes and improvements are made in the next few years we may have the satisfaction of knowing that we glimpsed their shadows some time before they arrived, and may even have assisted in hastening their arrival.

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## Refining Vegetable and Animal Oils*

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The terms "fat" and "wax" are commonly applied, more or less indiscriminately, to solid substances which have a greasy feeling to the touch and do not dissolve in water. Physically, waxes are regarded as having generally a harder consistency than fats. Chemically, fats are usually compounds of the trihydric alcohol, glycerol, $C_3H_5(OH)_3$; while the waxes are compounds of monohydric alcohols of large molecular weight; for example, cetyl alcohol, $C_{16}H_{33}OH$; myristic alcohol, $C_{30}H_{61}OH$, and cholesterol, $C_{27}H_{45}OH$. The names applied to some of these substances do not lessen the confusion; for example, "wool fat" and "spermaceti" are compounds of cholesterol and cetyl alcohol, hence are in reality waxes; while "Japan wax," a compound of glycerol, is actually a fat.

A fat, such as is indicated above, has among other physical properties a characteristic melting-point. Those which are liquid at ordinary temperatures are called *oils*. It is of such substances more especially that this communication deals with, although reference will be made to cocoanut oil, which may or may not be a solid at ordinary temperatures, therefore technically might be regarded as a fat.

It will be understood that the term "oil" as here used, is not to be associated with the natural or petroleum oils, *i.e.*, hydro-carbon oils, or the essential oils, both classes of which in general exhibit in a way the physical but not the chemical properties, necessarily, referred to above.

Fats are widely distributed in the vegetable and animal kingdoms, and, referring to the former only for the time being, we may say they are primarily glycerides of oleic, palmitic and stearic acids. These fats are found *mainly*, but not necessarily, in the reproductive bodies, such as spores and seeds. They are found in spores, sexual and asexual, of many algæ. In angiosperms they are widely distributed, replacing, wholly or in part, carbohydrates as reserve food material, and they are often associated with protein reserves; for example, in the seed from which colza oil, palm oil, cotton-seed oil, linseed oil, olive oil and cocoa butter are obtained. It is present, perhaps, as a reserve food material, associated with starch, in some tubers. The starch in the parenchyma of the stem of certain plants may be converted into fat during the winter's cold, and *vice versa*, when there is a rise of temperature in the summer time. Without venturing into the misty etiology involved, we may, for our purposes realize the likelihood of the presence of carbohydrates, proteins and other substances derived therefrom, as gums, etc., in oils obtained from these sources by the various means to be referred to later.

These oil-containing bodies invariably contain some coloring matter. Some of the coloring matters appear to be essential for certain of the changes just referred to. The most prominent pigment appears to be chlorophyll, an ester of tricarboxylic acid, chlorophyllin, $C_{33}H_{39}N_4Mg(COOH)_3$, and is the normal green coloring matter of plants. It may easily be broken down into substances that contain magnesium and substances that do not contain that metal.

Accompanying the chlorophyll are several pigments more or less insoluble in the cell sap; namely, carotin, ($C_{40}H_{56}$), yellow to red in color, and xanthophyll ($C_{40}H_{56}O_2$), a neutral body, yellow to orange in transmitted light. These substances may be destroyed by the action of such powerful chemical agents as concentrated sulphuric acid, especially if heated in the presence of oxygen.

*A paper read before the Franklin Institute of Philadelphia. From the June issue of the Journal of the Franklin Institute

Closely related to the fats is a group of substances known as phosphatides or lecithins. Occurring in egg-yolk to about 9 per cent, we find them to the extent of from 0.25 to 1.75 per cent in cereals and leguminous seeds, hence they appear in the oils extracted from the seed. They are glycerol esters, two of the acidities being neutralized by fatty acids, the third being saturated by a combination of phosphoric acid and choline, as shown here:

$$\begin{array}{l} CH_2O_2C.C_{17}H_{33} \\ | \\ CHO_2C.C_{17}H_{33} \\ | \\ CH_2 - OP.O.OH.O\,C_5H_{12}N,\,OH \end{array}$$

It is easily broken up by lipase, and hydrolized by boiling with alkalies and acids.

We always also find a small quantity of unsaponifiable residue in fats, which is in the main composed of the monohydric alcohols, cholesterol, $C_{27}H_{45}OH$, and phytosterol, the latter now being a generic term for a group of allied substances, with formulas varying from $C_{27}H_{45}OH$, (sitosterol) to $C_{30}H_{47}OH$ (stigmosterol). Cholesterol occurs in the bile, brain and blood of animals, and is the chief alcohol constituent of wool-fat. All vegetable fats contain phytosterol, the amount varying from 0.1 to 0.3 per cent, being even higher in the oil obtained from certain peas and beans, especially Calabar beans.

The oils are extracted by disintegration of the mass involving a disruption of the oil-sacs: (*a*) with a suitable solvent; (*b*) rendering by heat, with or without water; (*c*) or pressure, mechanical, applied when the mass is cold or hot.

If the mass extracted be selected and perfectly clean and fresh, the oil or fat obtained is usually neutral and "sweet." The exigencies of commercial operation do not admit of these conditions, however, so the oil or fat produced is usually acid and more or less contaminated. The contaminations may be quite normal and natural. They may be bacterial in nature and also contain the very interesting substances known as enzymes (lipase, for example) which induce hydrolysis; that is to say, they will cause any water present to disintegrate the fats (and other bodies) into simpler bodies. This may be facilitated by exposure to air and light, so that a freshly expressed oil that is sweet may soon acquire an unpleasant taste and odor. In some cases we say it becomes rancid, but in all cases the oil develops acidity, and the amount of the acidity of a particular oil is a function of time.

Under favorable conditions—and they are usually favorable—these changes take place within the oil-containing bodies, so that freshly produced oil is usually acid, which acidity increases on keeping. The enzymes are "killed," or decomposed, or at least their directive activity ceases when they have been exposed to a temperature of about 200 deg. C. It has not been considered a good procedure by the practitioners of the art of oil extraction and refining, however, to heat the oil to such a temperature immediately after its production; but I venture the opinion that the increased development of acidity in crude oil in storage or in transit to a refinery will be materially affected by such treatment. However, it will be necessary to be assured that substances charred or scorched at that temperature are absent.

As mentioned above, oils and fats are primarily glycerides of the saturated palmitic ($C_{16}H_{32}O_2$) and stearic ($C_{18}H_{36}O_2$) acids, associated with the fatty acids of several unsaturated series. For example:

1. Oleic acid, $C_{18}H_{34}O_2$, type $C_nH_{2n-2}O_2$.
2. Linoleic acid, $C_{18}H_{32}O_2$, type $C_nH_{2n-4}O_2$.
3. Linolenic acid, $C_{18}H_{30}O_2$, type $C_nH_{2n-6}O_2$.
4. Clupanodonic acid, $C_{18}H_{30}O_2$, type $C_nH_{2n-6}O_2$.
5. Ricinoleic acid, $C_{18}H_{34}O_3$, type $C_nH_{2n-2}O_3$.

The last is an hydroxy acid, which undergoes a particular polymerization under suitable conditions.

Most fatty oils, on exposure to the air, tend to thicken, due partly to oxidation and partly to polymerization, or both. Oils are, in fact, classified by many according to their drying qualities and tendency toward resinification. These properties play an important part in their utilization in the arts; and their treatment in refining is materially affected by the time which may have elapsed from actual production to their refining. For example, a freshly produced linseed oil may be profitably refined by a process which is inapplicable if the oil be "aged oil."

Oil, as stated, is normally a liquid, and we usually associate the phenomena of solution with a liquid. To be sure, this is a restricted conception, but will answer for our purposes. In this connection oil acts like water as a fluid. Water in motion carries fine particles suspended through long distances and deposits them in time, when fairly quiet, as we know from the formation of alluvial soils. Water carries certain substances in solution. These latter substances are sometimes colored and are partly fixed on the filter when that water passes through certain filtering media. For instance, we are able to adsorb Congo red from a water solution with filter-paper. Again, water carries certain substances which do not stop on the filter; they are invisible and show themselves only when we apply the ultra-microscope. These finely divided substances, not small enough to be in actual solution, will remain suspended in the water for long periods of time. They are called colloids. By various means, through heat, addition of an acid, an alkali, or a salt, by the influence of an electric current, or by the addition of other colloids, these very finely divided substances may be caused to agglomerate; that is, they may be converted into particles of sufficient size to be separated from the fluid by means of a filter. Exactly the same is true of oils. Organic colloid solutions may be viscous; the liquid particles are suspended in a liquid medium.

Many of the contaminating substances, referred to here in general, may be suspended in the oil, may be in solution in the oil, or may be in a colloidal condition in the oil.

It will, therefore, be quite apparent that crude vegetable and animal oils contain a variety of impurities traceable to a great variety of causes. The character of the crude oil depends not only upon the kind and part of the vegetable (wood, nut, seed, etc.) and animal (fish, whale, etc.) used, but the quality of the raw material at the time of expressage or extraction (rusting, rotting, fermentation, sprouting, heating, etc.) the method followed, the care exercised in the process, and the conditions to which the oil is subjected prior to its refining. In many cases, in fact, we find metallic soaps present in the crude oil, which soaps have resulted from an interaction of decomposition products of the oil and the rendering vessels.

No universal method for refining animal and vegetable oils is known. Your forbearance will not be taxed, however, even were it profitable, in discussing all the various proposals for fitting these oils best to the several purposes experience and practice have shown them to be applicable. A number of processes have been proposed, patented, or kept secret during the last 125 years. Around the knowledge and power of the practical oil refiner not a little mystery still obtains. Each individual oil presents its own problem, and even the same oil by name, obtained under different conditions, involves judg-

ment based on the knowledge of the chemistry involved, to secure the best and most economical results. Furthermore, the use to which the oil is to be put must be considered; for example, one wants acid oil for some paints and neutral oils for foods.

Some four general methods for refining oils have been and are being worked in practice. They are:

1. Treatment with steam (plain or superheated) whereby some coagulation results and many odoriferous substances are driven off. This does not diminish the free fatty acid content of the oil so treated.

2. Treatment with variable amounts of concentrated sulphuric acid (Gower, 1792) under determined conditions of heat and agitation with or without air. The oil contains certain substances which, when flocculated by the acid and temperature, fall down and mechanically (term used in several recognized authoritative books) carry down other impurities. This process does not diminish the acid content of the oil so treated.

3. Heating up under carefully regulated temperature conditions with fullers' earth, bone-black, etc., and filtering. This process also yields an acid oil.

4. Adding caustic alkalies, or alkaline earths, of an amount and strength determined by laboratory experience (Barreswil, beginning nineteenth century), heating to the "break," settling and drawing off the oil which floats upon the soap stock or "foots." This was supposed to give a neutral oil, but not until it had been washed several times with water.

Yet as late as last year a distinguished oil chemist, in a very interesting summary of the "Contributions of the Chemist to the Cotton-seed Oil Industry," said: "The chemist . . . found that the quality of the oil followed the free fatty acid present." An empirical formula has been worked out to show this relationship to the free fatty acid. The rule is: Multiply the f. f. a. by 2 and add 4; that is, an oil showing 2 per cent f. f. a. should give a shrinkage of 8 per cent. This is true only in a general way. I recently had a cotton-seed oil with 1.7 per cent f. f. a, which showed a shrinkage of 21 per cent by the official method of the Cotton-seed Crushers' Association.

The writer quoted above further said: "The chemist's greatest service to the industry has been in the refining of the oil . . ."

Wesson was here referring more especially to edible cotton-seed oil. In that connection Lewkowitsch, the lamented Anglo-German specialist in oil chemistry and technology, has said: "No chemically treated oil or fat can be looked upon as a product fit for human consumption." I confess inability to comprehend this sharp distinction as to what is meant by a "chemical." Oxygen from a chromate is a chemical; oxygen of the air is not. Sulphuric acid is a chemical; caustic soda is not. It may be interjected here that certain statements transmitted by texts and sanctioned by law call for clarification and revision. No treatment of an oil or fat, which involves purification, rendering it palatable, agreeable to the sight and avoids the introduction of constituents which may interfere with normal digestion should be forbidden. For fear of misunderstanding it may be stated here that the method described below complies with all the most rigid laws of all nations and even the above-mentioned uneven discriminations.

An oil that is acid is unsatisfactory as a food. Acid oils corrode the vessels and generate objectionable gaseous products when used as burning fluids. Acid oils corrode the bearings when used as lubricants, so it is desirable to have neutral oils for many purposes. Yet a neutral oil does not "cut" into white lead, for example, so an acid oil is preferred as a paint vehicle; but Gardner has pointed out that the oil should not be too acid.

I have been more concerned with neutral oils and their production, so shall confine my remarks to preparation of that class of substances.

The present customary practice for refining vegetable oils referred to (the fourth mentioned above) depends upon neutralizing the free fatty acids in the crude oil usually by agitating the oil with an aqueous solution of an alkali, the strength and the amount having been previously determined by laboratory tests, agreed upon as a standard, and then heating the mixture during agitation to a suitable temperature until the oil "breaks." The mass is then allowed to stand until the "foots" settle to the bottom of the kettle, when the supernatant oil is drawn off by means of a swivel siphon. According to the process of Chisholm, sodium silicate is added to facilitate the settling. Invariably some "dreg" floats on top of the oil. If this be very great its settling is sometimes facilitated by throwing salt on top of the oil in the kettle. The salt drags down some of the floating "dreg." In any event the oil drawn off is clouded, perhaps on account of the presence of some dissolved soap or globulated moisture or suspended matter—all doubtless colloidal in nature. This oil is then "brightened" after drawing off by throwing in small amounts of fullers' earth, heating again, and passing through a filter press. Sometimes, previous to this treatment with fullers' earth, the decanted oil is heated to 160 to 180 deg. Fahr. in a settling tank to cause the "foots" remaining in the oil to rise to the top, when it is skimmed off.

The time factor in settling (six to twelve hours) of the "foots" materially affects the completeness of the separation referred to above. Cocoanut oil sometimes requires forty-eight hours to settle. In any event the "foots" is wet with oil. The "foots" also entrains oil. Consequently during the rush season the efficiency of yield of refined oil must be sacrificed for speed and quantity refined. In other words, the more speed in refining, the more loss of refined oil, whatever the analysis, upon which purchase and sale are based, may indicate.

A process which would reduce the amount of oil entrained in the "foots" to a minimum, thus increasing the yield of refined oil, and one which would not be dependent upon the slow subsidence of the "foots" (that is, admit of rapid separation with consequent increase in capacity of a refinery), therefore, seemed to me not only to be desirable, but, if secured, would approximate the highest efficiency one might hope for in such an industrial operation.

I have succeeded in working out such a process, and shall now proceed to describe the principles involved and at the same time demonstrate it to you as an analytical method. I have pleasure in exhibiting to you samples of the crude and refined (by my method) oils from a variety of sources.

The technical laboratory tests with batches of twelve to twenty pounds have been verified in the factory on a commercial scale. Some of the samples exhibited are from factory runs.

The aims to be accomplished are:

1. To reduce the amount of oil entrained in the "foots," thus increasing the yield of "whole oil."

2. To reduce the time of contact of the excess alkali (necessary for the "break" and to secure the best "color") to the minimum.

3. A technological corollary calls for the utilization of any by-products.

It is to be assumed that all oils, good, bad and indifferent, are to be treated. However, this may not be necessary, as in some cases only the good, and perhaps the indifferent, oils are refined under the old practice at some places. Certain foreign markets call for a highly

colored oil, so they do not present the problem of bleaching.

In my investigations, lasting through several years, I have taken various kinds of crude vegetable oils from various kinds of sources with various (extreme) conditions and refined them. In many cases I have been told that no attempt would ordinarily be made to refine a particular oil, as it should be sent to the soap kettle, the corresponding price only being expected. Such oils would have represented much better values if they could have been refined by the usual practice. These oils in every case have yielded to my process, have been refined, and with a saving over the old processes. I may say, however, that China wood (tung) oil, castor oil and aged linseed oil cannot be economically refined by the process. I wish also to repeat that I am referring to the production of neutral refined oils only.

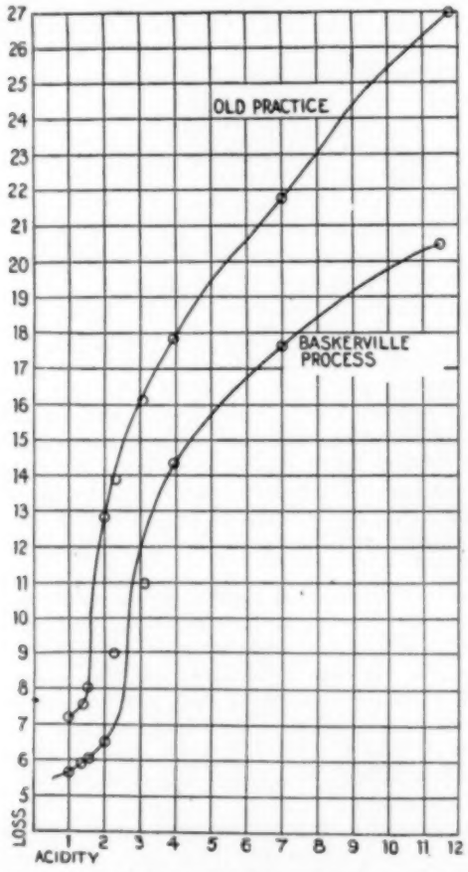


FIG. 1—COMPARATIVE LOSSES FOR COTTONSEED OILS

If we can get the "foots" into such a condition that it may be filtered and then squeezed, we may reduce the amount of "whole oil" entrained.

If we can do this immediately after the "break" and while the oil is still hot, we shall be able to reduce the time the "whole oil" is exposed to the saponifying action of the excess alkali necessary to secure proper color, avoid the present practice of necessary "cleaning," and the second heating.

I have called your attention to the presence of bodies, which in general terms are called colloids, in oils. These colloids may or may not be colored; may or may not make the oil turbid. I have also shown that some colloids may be and are coagulated by heat, some by acids, some by alkalies, some by salts or electrolytes, and in time will settle out. Colloids that have been coagulated or lumped may be filtered out. Some coagulated colloids in their formation adsorb coloring matter. The problem of economical filtration on the large scale necessary was one of great difficulty; in fact, so far as I am aware, it was unsolved previous to my investigation. Suitably prepared cellulose fiber will adsorb some coloring matter. It will bring about an agglomeration of the material precipitated from oils by treating the oil with alkalies and heating, and it will bind the particles together so that they may lose their somewhat slimy character and then may be easily filtered away from the oil in which they are produced. Short-fibered "linters" or "delint" is a suitable form of cellulose for some oils.

Therefore I add cellulose, suitably prepared, along with the caustic to the oil to be refined. The "break" takes place normally on heating as in the ordinary process, but the precipitated mass is in such a physical condition that it may be separated from the oil immediately by filtration.

As mentioned above, some colloids, perhaps colored, are thrown down by salts, so in certain cases some salt (1 per cent of sodium chloride) may be added. If there be a slight excess of water present, the sodium chloride serves also to "salt out" and soap in that water. The addition of salt, however, is not necessary in all cases.

I have also discovered that the tendency of the soaps formed by the caustic-alkali treatment to emulsify with the oil, or so to distribute themselves through the oil as to render their separation difficult, may be overcome by subjecting the oil, at a suitable stage of the treatment, to the action of an anhydrous salt which is capable of taking up water of crystallization, the preferred salt being dry sodium carbonate (soda ash), which, as is well known, is capable of taking up one, seven, or ten molecules of water of crystallization, according to temperature conditions. By such treatment the soaps which have already been formed by the treatment with caustic alkali, and which have become so incorporated with the oil as to be incapable of complete separation by ordinary filtration, are hardened or pectised, presumably by dehydration, and are so modified that they are readily separated by simple filtration. Sodium sulphate, which acts in the same way, may be used instead of soda ash.

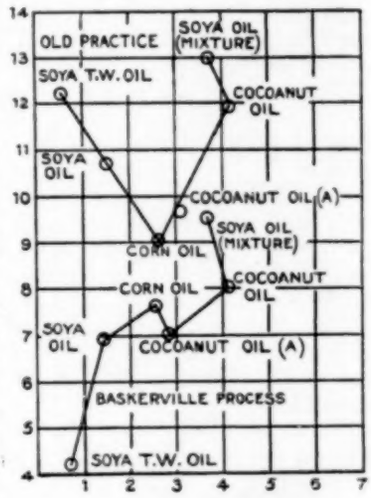


FIG. 2—COMPARATIVE LOSSES FOR SEVERAL OTHER OILS

The process is carried out by adding ordinarily 2 per cent of prepared cellulose (less than 1 per cent real cellulose) and a suitable amount of caustic soda (usually much stronger but actually less in amount than is commonly used). The whole is thoroughly basted by mechanical means and then heated to 45 to 65 deg. C. to produce the "break"; a determined amount of soda ash is added, after which it is filtered. At first some soap may pass through the filter-cloths. In that event, the first filtered oil may be run directly back into the refining kettle and pumped through the press until the oil is "bright." This usually occurs within a few minutes; in fact, the speed of filtration is directly dependent upon the speed of the pumps. This re-filtration also improves the color. This oil is neutral and can be deodorized and bleached, or both at once, or may be

stored safely. If linters is used, ¼ to ½ per cent of the dry cellulose is added.

These ideas are covered by four United States patents granted, Nos. 1,105,743, 1,105,744, 1,114,095, 1,130,698, and others applied for.

The danger of making a whole kettle into soap stock through failure of the refiner to be "on the job" is reduced to a minimum, as in several thousand trials this has not occurred, the trials being made by different people with various grades of oils of different character. In other words, the process is near "fool-proof." Any man of fair intelligence can operate the process, and the air of mystery surrounding the professional refiner is dissipated. The superintendent has a double check on the refinery by weighing the finished oil and cake. The daily reports when summed up should coincide with the annual inventory. I have known of cases where as much as 100,000 pounds of oil have failed to appear in the annual inventory, but were reported daily and had to be charged up to profit and loss at the end of the fiscal year when the operation was under the usual process.

The curves of Fig. 1 have been prepared from a series of cotton-seed oils very variable in character. Fig. 2 shows the comparative losses with several other oils. They show the comparative losses by the normal present practice and my process.

I have also been able to secure a further 1 to 3 per cent saving by subjecting the "cake" to hydraulic pressure. This extra saving is not shown in the charts.

The process is very rapid, the controlling factor being filter-press capacity. A study of plate filter-presses has indicated a preference for a center-feed press making 1½- to 2-in. cakes. The filter-press problem in connection with the process is not one of filtering area, but cake capacity. Presses, as the Kelly or Sweetland, which are dumped mechanically, meet the conditions better than plate presses. A new Sweetland press recently devised for this process promises the best results. It is provided with bottom exits for the refined oil, and the under bivalve swings through an arc of 165 deg. Monel metal filter-cloth makes the machine practically permanent. By a slight increase in filter-press capacity the output of a refinery may be doubled or even tripled.

### UTILIZATION OF BY-PRODUCT

The cake may be converted directly into soap, the cellulose becoming very finely comminuted. It is partially mercerized, partly converted into a colloid, and some of it forms an unobjectionable filler for some grades of soap, especially soap powders.

The cake may be "cut" with acid directly. The cellulose settles quickly in the aqueous layer from the black grease, which latter may be drawn off ready for market or use. When the cake is to be "cut," in order to reduce the amount of acid necessary, I prefer to use salt cake in place of soda ash as the "agglomerator."

A solution of niter cake, the process of Dr. Jeffrey Stewart of Philadelphia, patent assigned to the du Pont de Nemours Company, for the recovery of oil from soap stock, can also be used in cutting the cake. In view of the high price of acid at present, this may serve as an economical method for making "black grease."

Printed instructions for the use of the method in practice or as analytical procedure will be supplied to any who will write for them.

### SUMMARY

A process has been worked out, based on scientific principles, for preparing neutral oils, which possesses the following advantages:

1. The actual refined oil obtained is from 1 to 10 per cent more than now secured. Placed at a low average of 3 per cent, the process will save the cotton-seed oil industry in this country over $2,000,000 a year when prices are normal. The soja-bean oil industry, just developing in this country, can save 5 per cent. The peanut oil industry can save 6 per cent. The cocoanut oil industry can save from 3 to 5 per cent.

2. The process takes from one-tenth to one-third the time now necessary. Hence the capacity of the refinery is increased. This is of great importance during the rush season; in fact, its introduction will in economic efficiency perform the same rôle the tungsten filament lamp has played in the electric lighting industry, whereby the light production of a power station has been tripled.

3. The process gives a daily double check on the efficiency of the refinery.

4. The process is applicable to all grades of edible oils, which is not true with the common procedure.

5. Little new machinery is needed. The extra filter-press capacity called for will be more than paid for in the first year's profit.

6. The cost of chemicals is the same or less.

7. The by-product cake may be converted directly into a useful and commercial material.

The College of the City of New York,
New York City.

## Roentgen Rays and Crystal Structure*

(From London *Engineering*, June 2.)

To the general public the Roentgen rays remain the X-rays—the name chosen by their discoverer—a scientific mystery, more fascinating than radium, which, after all, does not do much more than shine and decay, a thing a conservative mind does not approve of. That in decaying radium generates helium, and that the disintegration proceeds through an extraordinary series of stages, ranging in time-period from minutes to thousands of years, is hardly understood by people who are quite able to appreciate the wonderful things that medical men have achieved with the aid of Roentgen tubes.

But the rays have done much more. They have helped to establish the actual existence of the atom and to reveal that the atom itself has a structure, and they promise to disclose the structure of the atoms in crystals —*i.e.*, the way in which the atoms are grouped and arranged in solids. The student of elementary science soon grasps that solids are dreadfully complex by comparison with gases. The chemist can analyze solids as well as fluids. He splits a compound into its constituent elements, finds out the relative numbers of atoms of each constituent, counts, in conjunction with the physicist—for it is mainly physical chemistry, of course—the actual number of molecules or atoms, and assigns definite structures to the constitutions of certain substances. Those constitutions are not mere speculations; for compounds have synthetically been built up from their elements on the basis of these researches.

But there science seemed to finds its limit. Calcite, it has long been known, is $CaCO_3$, like limestone; in the kiln the carbonate behaves as if it were made up of CaO and $CO_2$; in solutions it seems to split into the ions Ca and $CO_3$. How are the atoms of Ca, C, O actually grouped in the crystal? If they were differently grouped, their properties would probably be different. What are the forces and the laws? The X-rays promise to answer these questions.

The X-rays first puzzled scientists by penetrating through opaque substances and by refusing to be reflected, refracted, or polarized. But there was a strong suspicion almost from the first that they were, after all,

*We reprint this article from *London Engineering* as a supplement to the report of Prof. W. H. Bragg's lecture before the British Institute of Metals, published in our issue of June 15, page 694.—Editor METALLURGICAL & CHEMICAL ENGINEERING.

only rays of light, though of a light of extremely small wave-length, too delicate to be examined by ordinary apparatus. That assumption has been fully confirmed. The wave-length of sodium light is $5895 \times 10^{-10}$ Angström units (A.U.), or $5895 \times 10^{-8}$ cm., and X-rays have wave-lengths of the order of $10^{-8}$ cm., about one ten-thousandth of the length of ordinary light waves. In a diffraction grating the spacings between the lines should be of the order of the wave-length of the incident light; that condition is fulfilled by ordinary gratings with about 20,000 lines to the inch. To rule a grating with 10,000 times as many lines would be out of the question; the distances between the lines should be of the order of inter-atomic distances.

The ingenious idea occurred to Prof. M. von Laue then (in 1912) at Munich (he accepted a call to Zürich soon afterwards) to make use of the ordered array of the atoms in a crystal as an X-ray grating. The experiments made by Laue in conjunction with W. Friedrich, P. Knipping, J. Herweg, E. Hupka and others, were surprisingly successful; crystals of zinc-blende, copper sulphide, rock salt, diamond, zinc, sulphur, etc., behaved like three-dimensional gratings. That was the origin of the new line of research. The experiments were made by letting a beam of Roentgen rays pass through a crystal on to a photographic plate; the black central spot produced on the plate was found surrounded by small dark spots of greater or smaller intensity, arranged symmetrically to the center and lying on circles or ellipses passing through the center, each spot representing a reinforcement of the waves in that direction. Crystals of copper sulphate gave such a radiograph, the powdered crystals did not. But long exposures (of many hours often) were required, and the interpretation of the radiographs in all their striking regularity, as given by Laue, was very complex; he published a memoir on the "Diffraction of Short Electromagnetic Waves by a Crystal" in the Berichte of the Bavarian Academy, Munich, June, 1912.

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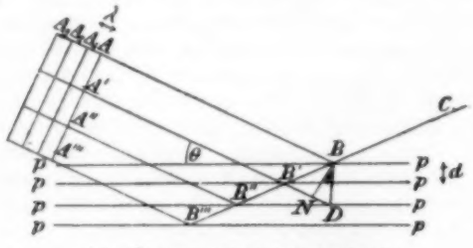


FIG. 1—REFLECTION DIAGRAM

of homogeneous light $A$, $A_1$, $A_2$, $A_3$ of wave-length $\lambda$ fall on a series of plane parallel surfaces $p$ (all at the same distance apart $d$), each of which reflects a small proportion of the incident light and transmits the remainder; then reflection and interference will result as with thin films, except that there are a great many reflecting surfaces instead of the two of the soap film. The wave $A\ B$ will partly be reflected, at its angle of incidence $\theta$, in the direction $B\ C$, and will partly travel on into the crystal; this latter portion is not indicated in the diagram. The waves reflected at $B'$, $B''$, $B'''$, etc., will, under certain conditions, pass out in the same direction $B\ C$, and in the same phase. To find the conditions, draw $B\ N$ at right angles to $A'$, $B'$ and produce $A'$, $B'$ until it cuts the plane $B''$ in $D$, which will be the mirror image of the point $B$ in plane $B''$; since then $B'\ B = B'\ D$, $A\ B = A'\ D$, and $N\ D = B'\ D$ (the distance by which the rays $A\ B$ and $A'\ B'$, and hence also the broken rays $A\ B\ C$ and $A'\ B'\ C$, will differ) will be $2\ d \sin \theta$. If $D\ N$ be equal to the wave-length $\lambda$ or to a multiple of it, the waves reflected at $B$ and $B'$ and similarly at $B''$, etc., will all be in the same phase and reinforce one another. If $D\ N$ differ only slightly from $\lambda$, the difference in phase will become greater and greater as the number of planes increases, and the resultant amplitude at $C$ will practically be zero. Thus reflection (as different from ordinary reflection) will only take place when $\lambda = 2\ d \sin \theta$. This will be a reflection of the first order, and to mark this we write $\lambda = 2\ d \sin \theta_1$. If $\theta_1$ be changed to $\theta_2$, there will be again reflection of the second order for $2\ \lambda = 2\ d \sin \theta_2$, and reflection of the third order for $2\ \lambda = 2\ d \sin \theta_3$, etc. At angles not satisfying this condition there will be no reflection.

Now in a regular crystal the atoms are probably arranged in parallel planes $p$, thousands of planes, all at spacings $d$; the $d$ may or may not be equal to the distance between two atoms next to one another in the same plane. The planes will not form continuous walls; that is not necessary for reflection, since a cluster of trees or a cloud can reflect sound waves as well nearly as a wall of rock. The atom-bearing planes are set in crystals at intervals of one or two Angström units. The characteristic X-rays used for this study are of the order of about half an Angström unit. This is a pregnant fact, to use the words of Prof. W. H. Bragg; the wave-lengths might easily have been ten or a hundred times the atom spacings, and then the investigation of crystal structure by means of X-rays would have been impossible. The method suggested by Mr. Bragg has been applied with brilliant success by Mr. Bragg himself and by his father, Prof. W. Henry Bragg, up till recently at Leeds, now at University College, London, and in this review we follow mainly the communications made by Professor Bragg, who quite recently lectured upon the subject again before the Institute of Metals and at the Royal Institution. The Bragg method, it may broadly be said, works with reflected rays, while the Laue experiments were with transmitted rays. In their main conclusions the two methods are in entire agreement.

The Bragg relation, $\lambda = 2d \sin \theta$, may be utilized in two ways. When the $\lambda$ is known, the $\theta$ are observed and the $d$ determined; once the $d$ values are determined, the $\lambda$ can be checked. As the wave lengths $\lambda$ of X-rays have been measured by independent methods, and the $\theta$ can be measured within one minute of arc, the new research admits of considerable reliability. The apparatus used by Professor Bragg is a kind of spectrometer without lenses. A pencil of homogeneous X-rays from an anticathode of rhodium (or some other platinum metal) falls through two narrow slits on a crystal which is mounted on a platform; the reflected ray enters the slit of an ionization chamber (about 5 cm. in diameter, 15 cm. long) charged with a heavy vapor (methyl bromide is now preferred, sulphur dioxide was first used); the resulting ionization is measured by means of an electroscope and microscope. The crystal or the ionization chamber, or both together, may be turned on the platform to determine the angles at which decided reflection and ionization occur. There is always a slight diffuse reflection from the crystal surface; but the ionization maxima are easily distinguished. As natural crystal faces are often rough or distorted, the crystals are sandpapered or etched with acid, or cleavage faces are taken; elaborate preparation is not required.

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In order to elucidate the relation of the spacings to the crystal form, Professor Bragg calls attention to wallpaper patterns. The position of any point in a pattern may be fixed with regard to two arbitrary systems of parallel lines crossing one another and cutting the pattern up into a number of rectangles or parallelograms. But unless the chosen points of intersection are the same corresponding, representative points, repeating at regular intervals, the parallelogram will not be a "unit" comprising the *ensemble* of the pattern.

Similarly the atoms of crystals are referred to "space-lattices," a kind of scaffolding of three-dimensional axes which, in the cubic system, cross all at right angles and at equal distances apart; in the other crystallographic systems the distances and angles are not all equal. When planes are passed through all the *X*, all the *Y*, and all the *Z* axes, the structure is cut up into cells, cubes, or parallelopipeds. Even the most complicated crystal can be referred to such a fundamental space-lattice, as indicated in Fig. 2. But a cell will not necessarily be a fundamental unit, unless it comprises at least the full number of atoms making up the characteristic molecule (possibly group of molecules) of the substance. Each unit can be considered separately, but to understand the growth of crystals, and the special relations it is better to consider the space-lattice as unlimited in all directions.

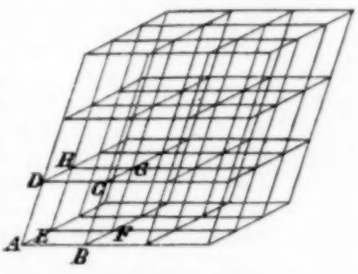

FIG. 2—SPACE LATTICE

In the crystal models the axes are represented by wires, and the atoms by beads strung on them. Supposing the atoms to be spaced quite regularly, as in Fig. 3, each little dotted square (in the wallpaper), or each cube on that base (in the crystal), would represent a unit. In the alternating grouping of Fig. 4 each dotted square would again give a cube (1 or 2), but only one of the two (2) would represent a unit (the *c* in Fig. 4 will be explained presently), and in Fig. 5 four of the

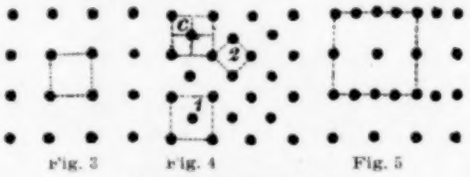

Fig. 3 Fig. 4 Fig. 5

ATOM ARRANGEMENTS

little squares would be required to make up a unit. The relations become clearer when small balls (atoms) are piled upon one another, which can be done in various ways; but the wire models are the most instructive, and when they are so held in the lantern beam (as Professor Bragg does) that corresponding axes and atoms coincide, the arrangement of the atoms in the various planes can clearly be recognized.

When the pencil of X-rays falls on the plane *A B C D* (Fig. 2), the formula $\lambda = 2d \sin \theta$ gives the *d* as distance between that plane and the next parallel to it, *E F G H*. When the pencil falls on the plane *A E H D*, the distance of this plane from *B F G C* is determined. But planes may also be passed, *e.g.*, through *E B C H* and corresponding points, cutting off the bevel of the edge *A D;* again, the nose of the crystal may be cut off. as Professor Bragg calls it, by a plane through *D* and *E B;* and so on. The values of *d* determined in this way may or may not be equal, but they will always be in definite geometrical relations. The larger the angles of reflection observed the closer will be the spacing.

Yet the deduction of the crystal structure from the *d* is not simple. In the case of a cubical lattice, for instance, the atoms may be arranged to cubes in three ways. When experimenting with rock salt (NaCl) and sylvine (KCl)—cubic crystals, very much alike in all properties—Mr. Bragg found that the *d* were not always in correspondence in the two crystals. There was parallelism when the atoms were referred: (*a*) to a simple cube (one atom at each corner), or (*b*) to a center cube (one atom at each corner, one in the center of the cube), but when the atoms were referred (*c*) to a face-centered cube (one atom at alternating cubic corners, one in the center of a face), as in Fig. 4 (*c*), the analogy between rock salt and sylvine failed. This was found by considering cubic planes, planes beveling off the edges, and planes cutting off the noses, as mentioned, and in this way it was established that KCl gives a simple cube of type (*a*), and NaCl a face-centered cube of type (*c*), while ammonium chloride is one of the rare examples of type (*b*). The face-centered cube (*c*) is very common, and the crystals of copper, silver, gold, etc., belong to this class.

So far all these measurements were merely relative, however. Absolute determinations of the *d* can be made when the atomic weight and the density of the material are known, and in the case of rock salt the distance between two planes (cubic faces) was found to be 2.81 A.U. The consideration of the relative intensities of the spectrum lines of the various orders constitutes another very important step. The intensity of a spectrum line depends upon the atomic weight of the atoms in the plane. When all the atoms in all the planes are the same, the intensities should diminish, according to a simple law, with the higher orders, just as in the case of a regular grating. That was found to hold for crystals of elements, and nearly to hold for KCl, because the atomic weights of K (39) and of Cl (35.5) do not differ much. But it did not hold for NaCl (Na = 23, Cl = 35.5). If the atoms of Na and of Cl were arranged in alternating parallel layers, the intensities should indeed alternate, just as in the case of a grating ruled with alternating strong and weak lines. Mr. Bragg correctly interpreted these features, and it follows that his value for the *d* of NaCl (above given), *i.e.*, 2.81 A.U., marks the distance between a sodium atom and the chloride atom next to it.

When the spacings between the parallel planes are not all the same, similar intensity variations should be observed. In the case of the diamond there is reason to assume that each carbon atom forms the center of a small, regular tetrahedron, with carbon atoms at the four corners, from which it is equally distant; the lattice is a face-centered cube all the same. When the model is built up, it is seen that the first layer of atoms lies in the base, the second layer at the distance 1 above the first, the third layer at the distance 3 above the second, the fourth at distance 1 above the third, and so on. It is as if a grating were ruled with lines spaced 1 and 3 divisions apart alternately. Such a grating would not

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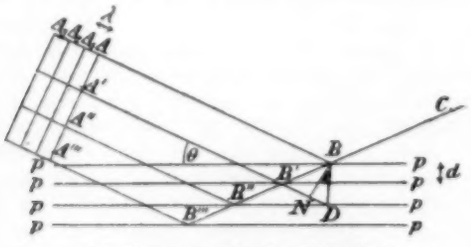


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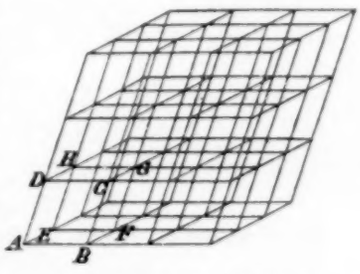
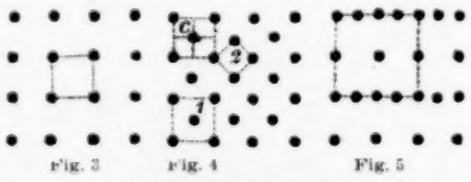


FIG. 2—SPACE LATTICE

In the crystal models the axes are represented by wires, and the atoms by beads strung on them. Supposing the atoms to be spaced quite regularly, as in Fig. 3, each little dotted square (in the wallpaper), or each cube on that base (in the crystal), would represent a unit. In the alternating grouping of Fig. 4 each dotted square would again give a cube (1 or 2), but only one of the two (2) would represent a unit (the *c* in Fig. 4 will be explained presently), and in Fig. 5 four of the



ATOM ARRANGEMENTS

little squares would be required to make up a unit. The relations become clearer when small balls (atoms) are piled upon one another, which can be done in various ways; but the wire models are the most instructive, and when they are so held in the lantern beam (as Professor Bragg does) that corresponding axes and atoms coincide, the arrangement of the atoms in the various planes can clearly be recognized.

When the pencil of X-rays falls on the plane *A B C D* (Fig. 2), the formula $\lambda = 2d \sin \theta$ gives the *d* as distance between that plane and the next parallel to it, *E F G H*. When the pencil falls on the plane *A E H D*, the distance of this plane from *B F G C* is determined. But planes may also be passed, *e.g.*, through *E B C H* and corresponding points, cutting off the bevel of the edge *A D;* again, the nose of the crystal may be cut off. as Professor Bragg calls it, by a plane through *D* and *E B;* and so on. The values of *d* determined in this way may or may not be equal, but they will always be in definite geometrical relations. The larger the angles of reflection observed the closer will be the spacing.

Yet the deduction of the crystal structure from the *d* is not simple. In the case of a cubical lattice, for instance, the atoms may be arranged to cubes in three ways. When experimenting with rock salt (NaCl) and sylvine (KCl)—cubic crystals, very much alike in all properties—Mr. Bragg found that the *d* were not always in correspondence in the two crystals. There was parallelism when the atoms were referred: (*a*) to a simple cube (one atom at each corner), or (*b*) to a center cube (one atom at each corner, one in the center of the cube), but when the atoms were referred (*c*) to a face-centered cube (one atom at alternating cubic corners, one in the center of a face), as in Fig. 4 (*c*), the analogy between rock salt and sylvine failed. This was found by considering cubic planes, planes beveling off the edges, and planes cutting off the noses, as mentioned, and in this way it was established that KCl gives a simple cube of type (*a*), and NaCl a face-centered cube of type (*c*), while ammonium chloride is one of the rare examples of type (*b*). The face-centered cube (*c*) is very common, and the crystals of copper, silver, gold, etc., belong to this class.

So far all these measurements were merely relative, however. Absolute determinations of the *d* can be made when the atomic weight and the density of the material are known, and in the case of rock salt the distance between two planes (cubic faces) was found to be 2.81 A.U. The consideration of the relative intensities of the spectrum lines of the various orders constitutes another very important step. The intensity of a spectrum line depends upon the atomic weight of the atoms in the plane. When all the atoms in all the planes are the same, the intensities should diminish, according to a simple law, with the higher orders, just as in the case of a regular grating. That was found to hold for crystals of elements, and nearly to hold for KCl, because the atomic weights of K (39) and of Cl (35.5) do not differ much. But it did not hold for NaCl (Na = 23, Cl = 35.5). If the atoms of Na and of Cl were arranged in alternating parallel layers, the intensities should indeed alternate, just as in the case of a grating ruled with alternating strong and weak lines. Mr. Bragg correctly interpreted these features, and it follows that his value for the *d* of NaCl (above given), *i.e.*, 2.81 A.U., marks the distance between a sodium atom and the chloride atom next to it.

When the spacings between the parallel planes are not all the same, similar intensity variations should be observed. In the case of the diamond there is reason to assume that each carbon atom forms the center of a small, regular tetrahedron, with carbon atoms at the four corners, from which it is equally distant; the lattice is a face-centered cube all the same. When the model is built up, it is seen that the first layer of atoms lies in the base, the second layer at the distance 1 above the first, the third layer at the distance 3 above the second, the fourth at distance 1 above the third, and so on. It is as if a grating were ruled with lines spaced 1 and 3 divisions apart alternately. Such a grating would not

give any second-order spectrum, and the second-order spectrum of the diamond was indeed found absent. The structure of zinc blende (ZnS) is exactly like that of the diamond; but there layers of Zn and S alternate at the distances 1 and 3, and as the atomic weight of sulphur (32.07) is only about half that of zinc (65.37), the second-order spectrum is weak, but not quite suppressed. The structure also would explain why zinc-blende has a polarity, while the diamond has not, for, with the atoms arranged in alternating planes of Zn and S, it would make a difference whether the light rays struck a zinc layer (coming from the left) or a sulphur layer (coming from the right). Professor Ogg of the Cape, at present working at University College, has quite recently found that antimony and bismuth can be referred to tetrahedra, like the diamond, but the central atom is not equally distant from the others in their cases.

We will briefly notice some more complicated cases. Calcite crystallizes in regular rhombohedra, which ought to be perfectly symmetrical about a certain plane. The X-ray examination shows that layers of Ca and of $CO_3$ alternate in certain parallel planes; in other directions layers of Ca, CO, O, O succeed one another; the symmetry does not appear to be quite perfect, however; that is to say, the left and right half of a section only coincide when the one side has been slightly shifted (gliding symmetry). Dolomite, which is a double carbonate of calcium and magnesium, is found to be built up of layers of Ca, $CO_3$, Mg, $CO_3$, Ca, etc., and there is no plane of symmetry—which is in accordance with the views of crystallographers. The complicated structure of magnetite ($Fe_3O_4 = FeO, Fe_2O_3$) can be imitated by piling up layers of oxygen atoms and fitting iron atoms into the interstices; some of the iron atoms appear as centers of oxygen tetrahedrons (4 O atoms), in which the iron is bivalent, some as centers of octahedrons (6 atoms of O), in which the iron is tervalent; the two sets have some atoms in common and differ by 60 deg. in orientation.

Professor Bragg's wire models, which can be taken to pieces, also help us to understand a puzzling point. The X-ray examination seems to concern itself merely about atoms, and not to recognize molecules. The one Na molecule in rock salt might equally well belong to any one of the six Cl atoms near it. But it is difficult to say in what condition the molecule really exists in the solid, and the X-ray examination does not entirely lose sight of the molecule. The whole crystal behaves like a big multiple molecule. If, in taking the model to pieces, a definite order is observed, the complex crystals of magnetite, as well as the simple rock-salt cubes, break up into their molecules. That shows that there are various methods of breaking up a crystal, and that the surface of a crystal is more or less like an unsatisfied set of atoms, to which set arrangements of fresh atoms will easily attach themselves—an exceedingly fruitful conception, which would account for the growth of crystals as well as for surface adsorption.

When crystals are heated the spacings between the atoms should widen, and the X-ray lines should be shifted and decrease in intensity; rock-salt crystals show this when heated in an electric furnace while being examined. Similarly, the expansion of crystals in different directions could be determined with very small specimens; the method does not require large specimens. The new method may also disclose why soft metals form hard alloys; further, in which way the hard and soft state of metals of Beilby, the surface films and cement films between the crystals, differ from one another. E. A. Owen and G. G. Blake have studied hard and annealed copper by X-rays. The examination, of course, presupposes a regular arrangement such as crystals offer. Experiments with glass, which is not crystalline, have failed, we believe, as they were expected to do. On the other hand, O. Lehmann has applied Laue's method to the study of liquid crystals; F. Terada has examined rock salt in the plastic state; P. Knipping has discovered a structure in liquid and in solid paraffin and in wax, and S. Nishikawa and S. Ono (likewise experimenting after Laue) discern crystals in fibrous asbestos, arranged along the fillers, but not in glass threads.

In their main conclusions, the two methods, of Laue and of Bragg, are in essential accord with one another, as we have already stated, and that should be so according to L. Ornstein and others. The objections to the former method are the long exposure, the unavoidable (though, in a sense, useful) presence of X-rays of different frequency under these conditions, the difficulty or impossibility of making quantitative measurements, and the difficulty of interpreting the results; according to G. Friedel, moreover, Laue's method does not bring out the full hemihedral symmetry. The quantitative ionization measurements (though not so accurate as the angle measurements) and the rapid working with homogeneous rays are the advantages of Bragg's method; the constancy of the radiation frequency can be checked by the comparison of the intensities of the different order spectra. Absorption, studied by C. G. Darwin, plays a part in both methods. It is satisfactory that Glocker agrees with W. L. Bragg and his co-workers as to NaCl and KCl, with A. Johnsen as to calcite, with E. Keller as to the diamond, and with P. P. Ewald and Friedrich as to zinc-blende, though not as to pyrites. On the other hand, F. M. Jaeger maintains that the theory is so far inadequate, on either lines, to deal with biaxial crystals; there is still one factor missing in the deductions.

X-ray investigation of crystals is young, of course. But there is a dearth of workers, and the war has cruelly put an end to the life of some investigators and has interrupted the work of others.

## By-Products from Coke Manufacturers

In a paper presented at the recent meeting of the American Iron and Steel Institute in New York, Mr. **William H. Childs**, president of The Barrett Company, New York, gave an interesting account of the present status of the recovery and use of the by-products from coking. He pointed out that the development has not been uniform here and abroad. Practically all of the pitch made in Germany, or in Europe, is used for fuel purposes, whereas in the United States the use of the softer grades of pitch has been carefully developed. In the United States coke-oven gas has been used for general city purposes since 1899 with success and increasing favor. Germany did not do this until 1910, but laid great emphasis on the use of oven gas in gas engines for electric power development. In this direction the United States has remained behind. At the present writing new ovens to the number of 2600 are under contract and will probably be completed by the end of 1917.

Many attempts have been made, mostly in gas retort practice, to increase the yield of **ammonia** from coal, in view of the large amount of nitrogen retained in the coke. The most promising of them seems to be the mixing of a little less than 2 per cent of caustic lime with the coal to be carbonized. Results for a year at an English gas works showed a gain of 1.68 lb. of sulphate of ammonia per net ton of coal, the operations being benefited rather than otherwise.

The latest coke-oven plants have adopted what is known as the semi-direct or direct methods of am-

monia recovery, in which the gas from the ovens, freed from tar, is led directly into the dilute sulphuric acid, the production of sulphate thus being accomplished without the intervention of washing water or redistillation. In the semi-direct system, which is much used in this country, the preliminary removal of tar involves the production of a certain amount of ammonia liquor, which can be treated in a still and returned to the oven gas before it enters the saturator, or can be made into crude, strong liquor. This process is called semi-direct, as all the ammonia is not made directly into sulphate. A direct system, in which no liquor is made, has also been developed and placed in operation in this country.

Some of the German plants put out a dried and ground sulphate, which, being entirely deprived of moisture by kiln drying, tests over 25.25 per cent $NH_3$ and brings a slightly higher price. A corresponding grade is made in this country.

Several methods have been proposed for making use of the sulphur in the gas to make sulphate of ammonia, rather than to resort to acid purchased from outside. Among these are the processes of Burkheiser and of Feld. The latter seems to offer a prospect of success, though the alterations in the usual methods of gas treatment are quite radical. It has not been tried in coke-oven work in this country as yet, although a modified form is in operation at the Central Union Gas Works in New York City and a plant is being installed at Chester, Pa.

The German cyanamid capacity is now said to be 500,000 tons per annum, and that of the Haber plant, at Ludwigshafen-on-Rhine, 300,000 tons of sulphate of ammonia, this being equivalent to 800,000 tons of sulphate of ammonia, and an increase of at least 500,000 tons over previous capacity. In order to induce private capital to build these plants, the Government has established a nitrogen monopoly, to continue in force after the cessation of hostilities. While the terms of this arrangement are not known, it is highly probable that any relief that they can get by shipping their surplus product into this country will be taken advantage of.

The prospects are that with the full operation of the existing plants, and those that will come into operation before the year is out, the production in this country for 1916 will exceed that for 1915 by 30,000 or 40,000 tons. With upwards of 2600 new ovens under construction, it is highly probable that the years 1917 and 1918 will register successive large additions. It is not out of the way to estimate the sulphate of ammonia capacity of the country at the end of 1917 as 375,000 tons.

**Coke-oven gas** is, in a way, the joker among the cards in the by-product coke man's hand. It may be worth a great deal for illuminating purposes, or it may be worth only its fuel value as against coal under steam boilers. In the first instance it brings from the consumer, let us say, about 60c. per thousand cubic feet, or, allowing for purification and distribution, about 30c. net. For fuel under boilers the usual price is about 4c. per thousand, depending on the price of the coal it displaces. Modern coking practice easily recovers 6000 cu. ft. of surplus gas per ton of coal carbonized. At 30c. this would be $1.80 per ton of coal, as against a credit of 24c. which would be the other extreme.

Where a new plant is under consideration there is an ample reward here for wise planning and successful negotiation. Unfortunately, success in finding such a market for the gas is in many cases a difficult matter. For example, a modern plant of, say, 40 ovens, which is about the minimum and corresponds to a 400-ton furnace, would produce about 3¼ million feet of gas per day. This, under ordinary circumstances, would supply a city of at least 150,000 inhabitans.

Authentic reports are at hand which show a yield from a recent coke-oven plant of over 12,000 cu. ft. of gas per net ton of coal, containing less than 5½ per cent of carbonic acid and nitrogen. Of this gas less than 40 per cent of the heat value was used in coking, so that the surplus corresponded to 7200 cu. ft. The coal was a mixture of 40 per cent low volatile and 60 per cent high volatile coal, which would average about 30 per cent volatile. The total amount of heat lost in waste gases and radiation at this plant was less than 4½ per cent of the total heat in the coal.

One important use, namely, for power development in gas engines, has not received the attenton in this country that it has in Europe. So far as information is available, the only large gas engine installation using coke-oven gas in this country is at Lebanon, Pa., where four 1200-hp. engines using gas from the Semet-Solvay plant there develop electrical power for operating the Cornwall Ore Banks. According to published data, gas engines aggregating over 200,000 hp. for operation with coke-oven gas has been installed in Europe by three of the principal builders since the year 1904. A guarantee of 1 hp. per hour with 27 cu. ft. of average gas is not considered out of the way, which would mean about 200 hp.-hr. per ton of coal, or for each modern coke-oven the capacity to produce 125 hp. continuously, as long as it is in operation. A battery of eighty ovens would yield 10,000 hp.

The actual recovery of **benzol** is a relatively simple matter. It is based upon the property of certain high-boiling oils to absorb the crude benzol vapors from the gas, and to yield them up again when heated to a temperature below their own boiling point. The oils employed for this washing are the so-called petroleum "straw" and tar creosote oils. English practice prefers a tar creosote oil distilling from 220 deg. C. to 250 deg. C., although heavier oils distilling from 250 deg. to 300 deg. are also used. All the American benzol plants use the petroleum straw oil because it is cheaper than coal-tar oils and the benzol can be more sharply separated from it in the type of continuous still used.

The washing of oven gas with oil for benzol is practically parallel to the washing with water to recover ammonia, the guiding principle being to bring the gas into intimate contact with a maximum surface of the cool washing liquid. The benzolized oil passes from the washer through a preliminary heater to the still, where the benzol vapors are driven off by a combination of direct and indirect steam. The exit oil is cooled and returned to the benzol washers, while the benzol vapors pass to the condenser and are delivered as light oil. This contains possibly 10 to 15 per cent toluol, and 45 to 55 per cent benzol, with small amounts of xylol and naphthaline. From the crude light oil the refined products are obtained by successive distillation and by treatment with the sulphuric acid and alkali. Benzol is usually made as 50 per cent, 90 per cent, and 100 per cent grades, the percentages referring to the amount that will distill over at 100 deg. C., not to actual purity. For pure benzol the specification requires that 100 per cent shall distill over within a range of 2 deg. C., within which range shall be the true boiling point of benzol.

Until recently there have been few gas works or coke-oven plants recovering **cyanids** from their gas in

this country. Late developments indicate, however, that several new plants are about to begin operations. Under normal market conditions there is probably little profit to be obtained from its recovery from coal gas.

The **coal-tar industry** in the United States has passed through two stages and is now entering upon a third epoch. In the first stage, from 1857 when tar was first distilled at Buffalo by Samuel Warren, until about the beginning of the present century, tar distilling necessarily followed "rule of thumb" methods and progressed in volume of material handled rather than in improvement of processes or development of new products and new markets. Great credit is due the pioneers in the industry for building up during this period a substantial business, particularly in the line of roofing material. They laid the foundations and at the same time outstripped in methods and in volume of business the roofing branch of the tar industry in all European countries. It is also important to note that during this epoch, in the year 1887, the H. W. Jayne Chemical Company, Philadelphia, was established for the production of naphthaline, refined carbolic acid, benzol and nitro-benzol. This was the beginning of the plant that in 1896 became the chemical department of The Barrett Company.

The second stage of the industry, comprising roughly the first decade of this century, was a period of engineering development attended by such progress along chemical lines as was necessary to the working out of largely increased production on the one hand, and more exacting demands from consumers on the other hand. The technical specification, as applied to paving, roofing and waterproofing materials, to creosote oil, to crude as well as to refined products, became an important factor. Laboratory control of products was inaugurated, requiring in many instances the working out of new methods for testing and analysis. In 1900 the Barrett company had, outside the chemical department, perhaps four or five chemists in its employ. In 1915 there were over fifty. During this decade and a half, large producers have had to spend much time and money in co-operative work on standards for methods and materials.

We are now entering into the third stage of development. The searchlight of newspaper and popular magazine attention has been thrown upon coal-tar, although it must be said that this naturally dark subject has not been highly illumined by the rays from that quarter. Coal-tar began to be regarded as a sort of Aladdin's lamp, and for many months it was no uncommon thing to receive inquiries for "50,000 gal. of tar a day" from respectable and previously conservative manufacturers of cast-iron pipe, sewing machines or porcelain bathtubs, who contemplated going into toluol at $4.50 per gal. as a profitable side-line.

"The portion of tar that can be used in making synthetic dyes and chemicals is only 10 per cent of its whole composition. I cannot overemphasize the fact that the continued growth of the tar industry, and its ability to take care of the largely increased supplies that are already in sight, depend entirely upon the disposal, at profitable returns, of the two principal items that constitute the great bulk of the product of tar distillation, viz.: **pitch** and **creosote oil.**

The total United States production of coal-tar in 1915 was approximately 180,000,000 gal., of which 140,000,000 were from by-product ovens and 40,000,000 from gas works. We have, therefore, three distinct types of tar: first, that from horizontal gas retorts, which may be expected to gradually diminish in quantity; second, that from by-product ovens, which it is estimated will reach 250,000,000 gal. in 1917; third, a much smaller but gradually increasing amount of vertical retort tar.

These three kinds of tar differ widely in characteristics. The difference may be roughly expressed by saying that horizontal or old-fashioned gas-works' tar is the heaviest, most viscous and contains a lower percentage of oils and more pitch. It also contains the highest percentage of suspended or "free" carbon—the portion of tar insoluble in benzol. Coke-oven tar occupies an intermediate position. It is usually lighter and contains more oils and less pitch than horizontal gas-works tar. Its free carbon content is lower. Vertical retort gas-works tar is lighter, less viscous and contains more oils and less pitch than coke-oven tar, and is also lower in suspended carbon. In order to meet specifications controlling the sale of products, it is generally necessary to combine two or more tars before distilling. Thus the problems of the tar distiller are rendered more complex by each new type of gas retort or coke-oven that is introduced, and by each change in coking time or temperature at existing plants.

The quality of tar may never be the controlling factor in deciding the type of oven or gas retort, or even in determining the heats and time of coking; nevertheless, some consideration of this phase may be worthy of the attention of coke-oven operators.

The reduction or disappearance of valuable constituents means, of course, that the tar is really worth less than before. In the past, such conditions have not influenced the price of tar. Doubtless the time will come when the real value of each tar, based on its composition, will affect the price.

There are at present about fifty distilling plants located in the United States. Many are naturally in the large cities, where the greatest demand exists for the road surfacing materials, paving pitch and roofing, that constitute the largest items of tonnage. Another reason for having tar-distilling plants located in large cities is the exacting service required in the delivery of road tars and paving pitch, in which hundreds of motor-driven tank trucks are engaged. Hence, freights from gas or coke-oven works are often 25 to 40 per cent of the value of the tar at shipping point.

The transportation, handling through plant, dehydration and mechanical features of tar distilling would require a separate paper. Over 1200 tank cars are now engaged in the transportation of tar and tar products, and on the Atlantic Coast there are about twenty barges of 25,000- to 300,000-gal. capacity. At one of the larger plants there are fifty storage tanks of 1000- to 20,000-bbl. capacity.

There are few if any proper uses for crude tar, both by reason of its varying character and because the presence of water and ammonia is objectionable in practically all cases. However, crude tar can be successfully burned in the same manner as heavy petroleum distillates and residues. At this point it may be well to say that tar itself as well as any of the crude fractions obtained from it, can replace petroleum fuel oils in steam plants, metallurgical furnaces, etc., whenever the relative value of the products makes burning a good economic policy. Tar oils have been successfully used in engines of the Diesel type in this country and abroad. In Germany tar oils are apparently the preferred fuel for these engines. Coke-oven tars average about 16,500 B.t.u. value, and the heavy distillates 17,000.

**Pitch** comprises from 50 to 80 per cent of the tar,

depending on the character of tar and the hardness of the pitch. Its uses are varied. Long experience in some fields and scientific research in others have determined what physical and chemical properties are desirable in pitches for each important use. In order to produce pitch meeting these requirements the tar distiller has especially to study, select and combine tars of different quality.

It is in the development of soft and medium pitches that the American tar distiller has far surpassed the achievements of his European contemporaries. We have extended the use of pitch into much wider fields, and in addition to that we have devoted infinitely more care to the production of pitches meeting the special requirements of each purpose. Large sums of money have been expended, not only on advertising such uses for pitch as the specification roof and road tar, but on the technical development of these products, and on educating the architects and engineers upon whose decision the choice of materials depends. It was frankly admitted by the delegates from England, France and Germany at the International Road Congress in London in 1913, that in technical work on the use of bituminous materials in road construction, American chemists and engineers were far in the lead.

The tremendous increase in the output of coal-tar from new and enlarged by-product coke-oven plants has made it imperative to find new uses for pitch. One rather promising outlet for very hard pitch is as pulverized fuel, where, in some cases, for metallurgical work, it can compete advantageously with fuel oil. Hard pitch normally contains less than one-half of 1 per cent ash and only about one-third to one-half of 1 per cent sulphur. For these reasons it can be used where pulverized coal would be out of the question on account of much higher ash and sulphur content. Work on another pitch outlet was started by our engineers nearly a year and a half ago, in the line of mixing with coke breeze or non-coking coals to supply the cementing properties necessary for satisfactory coking. It is very interesting to note, by frequent references in the English gas journals within the past few months, that the surplus of pitch in England has caused experiments to be made there along this line.

### Conclusions

(1) The by-product coke-oven industry is entering a period of rapid development. The by-product industries must expand to keep pace with it.

(2) This expansion must take place on lines adapted to our own conditions and to the large volume of materials involved. We may learn from foreign experience, but we must not be content to copy their methods.

(3) The great outlet for ammonia is in agriculture, in which direction there seems ample room for development, though it may come slowly and need fostering.

(4) The future field for gas is in an increased use for general city and industrial service, made possible by more widely extended distribution systems and by replacement of natural gas shortages, also in generating power by means of gas engines.

(5) There is an ample supply of benzol, toluol and homologues now recovered from our present domestic consumption of solvents. chemical derivatives and explosives. After the present abnormal conditions are past, the surplus will find ready use as motor fuel.

(6) New uses for tar must be found for an increased production of 100 per cent within two or three years, unless it is to be used as fuel. Refined derivatives, including phenol, cresols, naphthaline and intermediates, will be produced in sufficient amount to meet the demands of the color, drug and chemical manufacturers. The degree of development in this direction depends on the action of the Government with regard to protective measures and upon the co-operative effort of the industries involved.

The increased amount of cresote oil will tend to keep the price at such a level that European producers will seek to find outlets at home for their surplus.

The outlook for pitch is exceedingly problematical. Although new uses may be confidently looked for, it seems inevitable that a large portion of pitch must find its outlet in the fuel field.

(7) The by-product coke-oven, besides being an integral part of our steel industries, is our main source of benzol, toluol and phenol for munitions and the wide range of chemicals of scarcely less importance. It is also our only operating native source of combined nitrogen for nitric acid, and the only possible one outside of the processes for fixing atmospheric nitrogen.

## Chemistry of Portland Cement

The manufacture of Portland cement has grown so that the present output is about 100 million barrels per year. The mechanical part of the manufacture has undergone many changes. An article by **George P. Diekmann** in the *Journal* of the American Society of Mechanical Engineers, May, 1916, gives an interesting review of the chemistry of Portland cement.

The chemical process is carried out in the same way as laid down by the investigations of Fuchs and Vicat, two scientists of the early part of last century. Of course, the advanced knowledge of chemistry and the researches of eminent men have given us more and truer knowledge of the chemical composition of cement, and in order to throw more light and awaken more interest in research, a prize has been offered by the Prussian Government for the best essay on the constitution and hardening process of hydraulic cements, and efforts are renewed to solve this much disputed problem.

Portland cement is a hydraulic cementing material with not less than 1.7 parts by weight of lime to 1 part of soluble silica plus alumina and iron. The lime necessary to produce Portland cement is found as limestone called calcareous matter, and the silica, alumina and iron are found in clay, called silicious matter; the calcareous and silicious materials are mixed in proper proportions and burned to incipient fusion at a temperature of about 2600 to 2800 deg. Fahr. and the resulting clinker ground, to which 3 per cent of gypsum is added to regulate the setting time. Portland cement should not have more than 1.75 per cent sulphuric acid, which is equivalent to about 3 per cent calcium sulphate or gypsum, and not more than 4 per cent magnesia, although these specifications vary in different countries.

Chemically Portland cement is a salt composed of acid and basic constituents of such a composition that none of the bases are unsaturated. The main elements are silica, alumina and iron, known as the acids, and the lime and the magnesia are known as the bases. When limestone and clay have been intimately mixed and ground together to an impalpable powder, this then represents the mechanical mixture of acid and basic constituents, or what is the same, the silicious and calcareous materials. In subjecting this mechanical mixture of limestone and clay to the influence of heat at about 2600 to 2800 deg. Fahr., the mechanical mixture is converted into a chemical compound, and limestone and clay exist no longer in their original form, but are converted into an entirely new

chemical compound, a clinker, called tri-calcium silicate.

Various theories are advanced on the chemical composition of cement. According to Zulkowsky, there are existing two isomorphous compounds of the di-calcium silicate, the non-ortho active modification, the ortho silicates, the active modification and the basic meta-silicates. The meta-silicate is considered a strong hydraulite, having hardening properties in contact with water. The ortho silicate has no hydraulic properties and disintegrates. In other words, silica, lime, alumina and iron must be present in such a ratio that certain chemical action is produced.

According to Le Chatelier, whose work has long been considered the modern theory on cement, cement is a tri-calcium silicate. Professor Michaelis recently advanced the colloid theory, which might give an entirely new view on the constituents of cements. Clifford Richardson made a very thorough microscopic examination of cement clinker and his studies are very interesting. According to these theories, the total basic constituents of any cement expressed in equivalents should not be greater than three times the total acid constituents expressed in equivalents. According to Michaelis, the composition of the cement should be such that the ratio of the acid constituents to the basic constituents shall be from 1.8 to 2.2 times larger by weight. This formula is the one most used and enables the composition to be judged from the analysis very quickly.

In Portland cement each element performs a certain function, and therefore the elements should have a certain ratio to each other, as follows:

Lime to silica.... 2.8:1 minimum; 3.2:1 maximum;
Alumina to iron.. 2.5:1 minimum; 3.5:1 maximum;
Iron to alumina.. 2.0:1 minimum; 3.0:1 maximum.

The chemical composition of Portland cement is very uniform and is usually as follows: silica, from 20 to 23 per cent; alumina, from 5 to 8.5 per cent; iron oxide, from 1 to 4 per cent; lime, from 60 to 64 per cent; magnesia, from 0.5 to 3.5 per cent, and sulphuric acid, from 1.5 to 2.5 per cent.

There are certain formulae for the calculation of the proper proportion of each raw material in relation to the others according to chemical composition and physical nature. One of the most convenient which is used is a formula according to C. Shoch by which the desired ratio can be determined according to the analysis of the materials which are calculated on the total silicates containing silica, alumina and iron. However, no matter what formula might be chosen, the Portland cement raw mixture contains usually from 42 to 43 per cent lime and 20 to 21 per cent silica, or a ratio of 2:1; this may sometimes be as low as 1.8:1 and as high as 2.2:1.

Portland cement contains usually from 5 to 8 per cent alumina. With an increased amount of alumina the cement becomes quicker setting, and if the alumina content reaches about 9 per cent, the cement becomes very quick setting, due to the formation of a tri-calcium aluminate. If alumina is present in quantities exceeding a certain limit it is considered detrimental, as it not only produces a quick-setting cement, but has a greater expansion power, especially if hardening takes place in sea water or water containing alkaline matter. The aluminates are parts of a cement which are most easily acted upon by certain salts contained in sea water, forming water soluble compounds which in time destroy the cement.

Iron in a cement combines with lime and acts as flux similar to alumina in lowering the fusing point between the acid and basic constituents. Iron will give cement a darker color. Alumina might be replaced by iron giving an excellent cement for marine work. In fact, there are now manufactured in Germany iron Portland cements which are claimed to be superior to ordinary Portland cements for sea water construction.

The effect of magnesia on cement is still a matter of investigation, but all agree that a large amount of magnesia is detrimental to cement. It is of so much more danger than other constituents as the expansive power of magnesia will occur long after setting. The general specifications call for not more than 4 per cent magnesia, while the German specifications allow a limit of 5 per cent. Candelot in his investigation stated that magnesia produces the same effect as free lime.

In recent years the many accidents occurring in construction where magnesia cements have been used have drawn attention to this question. Magnesia cements give very good results in tests, and masonry made with these cements shows desirable solidity sometimes during several years, but after a certain time swelling begins to manifest itself, and with such intensity that nothing can resist it. Candelot stated that a rod of magnesia cement 1 m. long was found to elongate 26 mm. in three years. Dykerhoffer stated, after very thorough research work in which he studied the effects of magnesia, that when magnesia is added to the raw material or substituted for an equivalent portion of lime, it causes a decrease in strength in the resulting cement if present in a proportion greater than 4 per cent. Cracking occurs only with 8 per cent magnesia or more.

It is known that magnesia compounds become hydrated much more slowly than calcium compounds, and this is evident as although concrete consisting of calcium silicate and aluminate will harden and set in a proper manner, cement containing magnesia either in combined form or as free magnesia will, due to the slow hydration after setting, undergo changes and molecular movements, causing expansion and cracking. The natural cements contain usually from 16 to 22 per cent magnesia, but here the magnesia has no injurious effects as in Portland cement. The trouble lays in the burning, as while Portland cement raw mixture is burned at a high temperature, in effect incipient fusion, forming a very dense clinker, in a natural cement mixture only a moderate heat is applied to drive off the carbon dioxide. The resulting clinker is soft and the magnesia is hydrated here very quickly; the hard clinker obtained with this process is picked out and not used.

The amount of sulphuric acid in a Portland cement should not exceed 1.75 per cent, but according to the German specifications 2.5 per cent is allowed. The presence of sulphuric acid in a cement is due to the addition of calcium sulphate, which is added in the form of rock gypsum or burned plaster before or after grinding the clinker. Portland cement clinker is more or less quick-setting, and, in order to retard or regulate the setting time, a small amount of gypsum is added. The amount depends on the composition of the raw materials—usually from 2.5 to 3 per cent is added.

Portland cement clinker usually contains about 0.1 to 0.4 per cent of sulphuric acid due to the sulphates in the raw materials, which are mostly converted by the high heat to volatile acid and driven off. A small amount of this acid is also due to the ash from the coal, which becomes part of the cement. If the burning or fusion takes place in a reducing atmos-

phere, the sulphates will be converted to sulphides, forming mostly iron and calcium sulphides, which will again be oxidized to sulphates. The small amount of calcium sulphate added to cement retards the setting time.

When cement is mixed with water chemical action takes place at once, according to Le Chatelier. The hardening process is due to a deposit of inter-locking crystals from a super-saturated solution, part of the water entering into chemical combination. There are two distinct chemical actions which take place, the setting or hydration and crystallization or hardening process. The process of setting is due to the formation of aluminates of calcium, developing a certain degree of heat, but the addition of calcium sulphate prevents quick hydration by forming sulphate of aluminate of calcium, which hydrates very slowly without developing heat.

Along with the hydration the hardening process is beginning very slowly. The tri-calcium silicate is decomposed by the action of water to mono-calcium hydrate. The process of crystallization begins very slowly, and as time goes on the crystals become more closely interlaced, forming a denser body and attaining a stone-like character, called hydraulic character, and it is this process which makes Portland cement such a high-grade hydraulic mortar. If once formed, no action of the elements can disturb its increasing crystallization, and as Portland cement is the binding medium in concrete, any suitable aggregate will become embodied and form an unseparable bond of natural stone.

Portland cement develops in the hardening process about 40 per cent of its total strength in the first 24 hr., 60 to 70 per cent in 7 days, 80 to 85 per cent in about 30 days, and it will attain its maximum strength in about 6 to 12 months, depending on the season of the year. This explains why a cement of 24 hr. is not as strong as at 7 days, and at 7 days not as strong as at 28 days.

## Science Linked with Industry

Presidential address delivered at the dedication of the new Massachusetts Institute of Technology in Cambridge, Mass., June 14, 1916.

BY RICHARD C. MACLAURIN

We are here to dedicate a noble group of buildings to a noble purpose. The buildings speak for themselves. They will form an enduring monument to the skill of the architect, the capacity of the engineers of construction, the devotion of the faculty that has planned so much of their detail, and the splendid public spirit of the anonymous benefactor whose gift they are. That gift has won admiration not only for its munificence but for the unostentatious manner in which it was made and for the patriotic purpose to which it has been devoted. It will have far-reaching consequences for the country at large, for its aim is to strengthen American industry at the base by fixing it firmly on the solid rock of science.

How striking is the change that has come over the world in its view of the relation between science and industry! Each is of venerable antiquity, for while science in its growth has gaged the intellectual development of mankind from the beginning, its application to practical affairs is coeval with the manifestation of the scientific spirit. In the early days, however, the two things, science and practice, rarely, if ever, went together, and were often regarded as antagonistic. To-day we are far removed, indeed, from the aristocratic contempt for practical things so freely expressed by Plato and even by Archimedes himself. No such feeling has been manifested by the great modern masters of science such as Newton, Pasteur, Faraday, or Kelvin, although a trace of it may be found occasionally among the lesser lights.

We do well to rejoice in this change of heart and outlook, a change that means so much to the world; but in so doing we should not fail to recognize our debt to the past. So we have clothed these laboratories in the forms of classic art, and have done this not merely that students may be influenced by the beauty of their simplicity, but that they may observe how well that art adopts itself to thoroughly modern needs. Thus may they have a practical proof of the error of supposing that old things are of necessity useless and a forcible reminder that much that is most potent in our life to-day has its roots deep in the past. For a somewhat similar reason we have inscribed on the walls of these buildings the names of the imperishable dead in the hope that they may inspire our students with the thought that each succeeding age inherits the intellectual wealth of all that has gone before and fails in its duty unless it makes it its high vocation to hand on the heritage that it has received and to enrich that heritage by contributions of its own.

But although we are not unmindful of what we owe to those who have preceded us, our look must be ever ahead. The opportunity immediately before us is alluring in the extreme. The greatest war in history will inevitably mark the end of one era and the beginning of a new. For some time before the war, but particularly during its progress, the world has been given an impressive demonstration that the methods and the means of science are indispensable in many a practical field. In the new era that is about to dawn we must take our share in making the dominance of the scientific spirit pre-eminent in every phase of industry and practice. In that era no half measures will avail. We must get it into the minds of the rising generation that for success nothing must be done haphazard or by "rule of thumb." All must be orderly and logically planned, resting ever on the solid ground of fact, and industry like science must be matter not of expedients nor of guesses, but of laws.

Our prosperity as a nation, perhaps even our very existence, must depend on the extent to which we assimilate this doctrine. In the great industrial struggle that will follow the present war, and that will go on indefinitely, many of the advantages of this country will be offset by serious disadvantages. If victory be ours, it will be no easy victory, but assuredly we have a splendid opportunity of success if only we organize our industries on a scientific basis. We must train men in the methods of science and make the proper use of these technically trained men when we have got them. This—the adequate supply of properly trained men—is the cardinal doctrine of industrial preparedness recognized by thinking men to-day as one of the greatest necessities of the times.

The opportunity for this country to take and keep the lead industrially is constantly before us in these days, but there is another opportunity seldom, if ever, mentioned, that is in some respects even greater. The center of intellectual achievements in the world has passed in turn from Egypt and Babylonia, to Greece, to Alexandria, to Constantinople and to western Europe. Is it to cross the Atlantic? If this be so, the intellectual leadership must accord with the genius of our people for practical affairs. That genius will inevitably show itself chiefly in industrial pursuits and industry will continue to attract a large proportion of the best minds of the country. Hence we must

have industry linked with science, not merely for the benefit of industry but for the sake of science. Of course, our American science will never grow as it should if it is cramped by a short-sighted policy as to what is useful. But if the value of science to industry be generally appreciated, science will be free to expand in any direction, and if it be pursued with the same energy and intellectual power that have been applied to business, there is no reason why America should not become the intellectual leader of the world.

Here is a great hope and a great national opportunity. The problems that it presents are not local and must be looked at from no merely local point of view. They demand the co-operation of all, and as a step toward that great end, Harvard and Technology, each national in its scope and influence, are here combining for the common good.

And so, in the presence of representatives of other learned societies from all parts of this country and from abroad, inspired by their sympathy and their achievements, we dedicate these buildings to the great cause of science, linked with industry.

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## Synopsis of Recent Chemical and Metallurgical Literature

### Storage Batteries

**Theory of the Lead Accumulator.**—Plante and Faure considered that when a lead storage cell is being discharged, the $PbO_2$ plate changes to PbO and the Pb plate to PbO so that the lead accumulator would be simply what we now call an "oxygen-lift" cell. However, this theory was abandoned at an early date in favor of the double sulphate theory, according to which during a discharge the $PbO_2$ plate as well as the Pb plate are changed to $PbSO_4$. While this theory has been widely accepted, it has also been opposed by some, and the latest modification proposed is that of CH. FÉRY in a French Physical Society paper (*La Revue Elec.*, June 2, 1916). On the basis of experiments carried out by him jointly with M. Fournier, he proposes the following theory. The "negative" plate only behaves as assumed, being Pb at the end of the charge and $PbSO_4$ at the end of the discharge. On the other hand, it is claimed that the "positive" plate at the end of the charge is $Pb_2O_7$ and $PO_3$ at the end of the discharge, so that the total reaction during discharge would be given by the equation $Pb_2O_7 + H_2SO_4 + Pb = 3\ PbO_2 + H_2O + PbSO_4$. The change from $PbO_3$ to $Pb_2O_7$ is endothermic and absorbs 9000 calories, while the change from PbO to $PbO_2$ sets free 12,000 calories.

### Cement

**Properties of Portland Cement.**—A study of the compounds existing in Portland cement is very important to the cement industry. Such work has been undertaken by the Geophysical Laboratory of the Carnegie Institution in Washington, and described by GEORGE A. RANKIN, in the *Journal* of the Franklin Institute for June, 1916.

Ninety per cent of an average Portland cement consists of the three oxides, $CaO$, $Al_2O_3$ and $SiO_2$. It is to be expected, therefore, that its properties are due mainly to the presence of the above three components, and that the relatively small admixture of the other oxides exerts at most a wholly secondary influence. It has been shown that good Portland cement can be made from three pure oxides, lime, alumina, and silica, in the proper proportions.

Now, ordinary chemical methods enable us to ascertain the aggregate proportion of each oxide present, but they yield us no information as to the manner in which these oxides are combined with one another—in other words, as to the substances which actually are present in the clinker and are responsible for its characteristic properties. The determination of this question is very important, for this reason; that, until we know what these substances actually are, we cannot hope to improve the quality in any desired direction, except by cut-and-try methods; and it is generally recognized that such empirical methods are much less certain, and take a vastly longer time to reach the goal, than methods based on a real knowledge of the factors in the problem. The determination of this question has been the object of a very large number of investigations; but the experimental basis of most of this work has been altogether insufficient to decide the several questions at issue. There has been in general a failure to realize the fact that a system so complicated as this can be unravelled only by proceeding systematically, using as a guide the principle known as the phase rule and establishing definite criteria for the recognition of the several substances which occur.

Cement clinker is a mixture of substances of very similar properties, and is, moreover, exceedingly fine grained, as a consequence of which it is a matter of some difficulty to make quantitative determinations of the constituents; but this difficulty can be surmounted by studying separately each of the presumable constituents of the clinker and determining definite values of certain properties which serve to characterize it and to distinguish it from other possible constituents. Accordingly the first problem is to isolate and determine all the possible compounds of lime, alumina, and silica which we may expect to find in Portland cement clinker, to establish their relations at high temperatures, and to ascertain their optical characteristics which constitute the most convenient and satisfactory criterion of the identity of the several substances.

In order to work out this system completely it proved necessary to investigate about 1,000 different mixtures of these three oxides and to make about 7000 heat treatments and microscopical examinations of the resultant products. Each such mixture, which was always made up of especially pure materials, was alternately fused and ground to a fine powder, the fusions being made in a platinum crucible to avoid contamination, in order to obtain a thoroughly-combined product. Each of these products was heated in an electric furnace, the temperature of which was carefully controlled and measured, until all changes had ceased, when it was quickly chilled; and the resultant material was subjected to a complete optical study. This procedure, carried out systematically, enables one to determine the crystalline phases present at temperatures ranging from that at which melting begins to that at which the charge is completely melted; and thus to ascertain the melting temperature and optical properties of all compounds of lime, alumina, and silica which form when any mixture of these three oxides is heated.

The results are summarized as follows: The value of Portland cement depends upon the fact that when finely powdered and mixed with water it forms a hard mass; and the strength and permanence of this mass depend upon the constituents of the cement. The major constituents are tricalcic silicate, dicalcic silicate, and tricalcic aluminate. Of these constituents, the compound tricalcic silicate is the one which hardens and develops the greatest strength within a reasonable time. This most important constituent, which is the one formed wih the greatest difficulty, makes up only 30 to 35 per cent of an average normal Portland cement. It may be said, therefore, that the essential process for the manufacture of Portland cement is the formation of

this compound, and that any improvement in this process yielding an increased percentage of tricalcic silicate will increase the cementing value of Portland cement. In order to determine the most economical process for producing tricalcic silicate in the highest percentages, it will be necessary to study the rate of formation of this compound in a series of mixtures of various substances; this, in turn, necessitates the determination of the equilibrium relations of tricalcic silicate at high temperatures in such mixtures. Such a procedure will lead sooner to the discovery of the optimum composition in various cases and for various purposes than the empirical, cut-and-try methods which hitherto have been the only methods tried.

### Fire Brick

**Effect of Compression Loads on Fire Brick.**—Some interesting experiments on the effect of compressive loads in reducing the temperature at which fire brick will soften, are described in the London *Engineer*, June 9, 1916. The experiments were performed by Dr. J. W. MELLOR and Lieut. B. J. MOORE and described by them in a paper presented to the English Ceramic Society of which the above is an abstract.

The apparatus consisted of a cylindrical electric furnace with an inner core of refractory material, surrounded by granular graphite, which is retained in place by a thick fire-clay cylinder, and this in turn surrounded by an iron casing. Iron electrodes are fastened in connection with the graphite. The clay to be tested is molded in the form of a cylinder and placed on a block which forms the bottom of the furnace. By a lever arrangement something like a piston rod through the top of the furnace different weights can be supplied to the clay to be tested, and the temperature at which the piece fails is observed.

The conclusions from the tests are as follows:

(1) The squatting temperature of fire-clays is reduced by a compressive load. The greater the load, the lower the squatting temperature.

(2) The decrease in the squatting temperature with unit increase of load is directly proportional to the squatting temperature, and equal to $k$ times the squatting temperature.

(3) The relation between the squatting temperature T and the load $w$, expressed in pounds per square inch, is given by the expression

$$T = C_e^{-kw},$$

where C represents the squatting temperature of the briquette without a load, $k$ is a constant the numerical value of which is dependent upon the particular clay, on the mode of manufacture of the briquettes, on the grain-size of the clay, etc., and $e$ is the regular exponential constant. The temperature can be expressed in degrees Centigrade or else in terms of Seger cones. To conform with industrial conventions the latter method has been followed.

(4) The more siliceous the clay, the less the difference between the squatting temperature with or without a load; and, in most cases, the more nearly the composition of the fire-clay approaches that of china-clay, the greater the difference between the squatting temperatures with and without a load. The squatting temperature of china-clay is lowered approximately one cone for every increase of 5¼ lb. per square inch in the load.

### Iron and Steel

**Relation Between Cutting Efficiency and Hardness Tests of Tool Steels.**—In a paper presented at the annual meeting of the Iron and Steel Institute in London, Professor J. O. ARNOLD, discusses the lathe efficiency of tool steels in its relation to hardness tests. He states that in recent papers read before the Institute there has been a tendency to regard the Brinell and scleroscope numbers as an approximate measurement of the cutting efficiencies in the lathe. This he states is incorrect as there is no relation between Brinell hardness and cutting efficiency. The efficiency depends almost entirely on the thermal stability of the simple or compound hardenites in the hardness steel. Table I shows tests made on two different types of steel.

TABLE I

| University Steel No. | Type of Steel. Compositions nearly Identical for each Type | Duration of Tests in Minutes and Seconds before Breaking Down | | | | Efficiency. Cubic Inches of Standard Hard Steel Shaft Removed | | | | Brinell Hardness No. Pressure, 3000 Kilos.; Ball, 10 Millimetres Diameter | Scleroscope Hardness No. Average of Four Tests |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1st Grind | 2nd Grind | 3rd Grind | Mean | 1st Grind | 2nd Grind[1] | 3rd Grind | Mean | | |
| | | M. S. | M. S. | M. S. | M. S. | | | | | | |
| 1523 | Tungsten-chromium | 10 7 | 11 45 | 9 26 | 10 26 | 47.4 | 56.3 | 43.3 | 49.0 | 600 | 82.8 |
| 1527 | Tungsten-chromium | 11 25 | 12 35 | 10 32 | 11 32 | 54.7 | 61.4 | 49.4 | 55.2 | 629[2] | 80.5 |
| 1533 | Tungsten-chromium | 10 26 | 11 50 | 11 31 | 11 18 | 48.9 | 56.7 | 55.0 | 53.5 | 578 | 80.3 |
| 1522 | Tungsten-chromium-vanadium | 14 17 | 17 50 | 13 40 | 15 19[3] | 72.3 | 96.2 | 68.0 | 78.9 | 600 | 80.3 |
| 1524 | Tungsten-chromium-vanadium | 17 2 | 17 49 | 16 57 | 17 24[3] | 91.0 | 95.2 | 89.1 | 91.8 | 600 | 75.5 |
| 1528 | Tungsten-chromium-vanadium | 16 2 | 17 52 | 16 57 | 17 24[3] | 84.1 | 95.7 | 89.1 | 89.6 | 600 | 76.3 |
| 1534 | Tungsten-chromium-vanadium | 15 21 | 17 10 | 15 45 | 16 27[3] | 79.0 | 91.6 | 81.1 | 83.9 | 600 | 81.0 |

*Note.*—The Brinell and scleroscope hardnesses were taken as near as possible to the hardened cutting edges of the various tools.

[1] It will be seen that with both types of steel the maximum efficiency is obtained on the second grindings of all seven tools.

[2] Duplicate test 629.

[3] Throughout these tests the cutting edge of the tool was red-hot at the breakdown points, and indeed for about five minutes previous to breaking down.

**Influence of Carbon and Manganese Upon the Corrosion of Iron and Steel.**—Some interesting and valuable results on the effect of various amounts of carbon and manganese on the corrosive properties of iron and steel have been obtained in experiments carried out by Sir ROBERT HADFIELD and J. NEWTON FRIEND. The results were described in a paper presented at the annual meeting of the Iron and Steel Institute in London. The authors state that there has been much conflicting information in regard to the effect of manganese in steel, and no conclusive evidence has been advanced. The present research was undertaken with a view to throwing further light upon this intricate problem. Of late years it has been repeatedly emphasized that different corroding media exert very different effects upon iron and steel, no one metal resisting all kinds of corrosion equally well. The authors considered it essential to test the steels in a variety of ways, viz., by exposure successively to tap water; sea water; alternate wet and dry (a process closely corresponding to a changing climate), and by exposure to 0.1 and 0.5 per cent sulphuric acid.

The results are briefly as follows:

The addition of carbon from 0.03 to 1.63 per cent to

pure iron containing less than 0.2 per cent of manganese, results in—(*a*) A steadily increasing rate of corrosion both in tap-water and in sea-water, slight maxima being observed in the neighborhood of 0.6 to 0.8 per cent carbon. (*b*) An initial fall in corrosion, with a rapid rise to a maximum with 1.05 per cent carbon in the wet and dry tests. (*c*) A rapid rise in corrosion to a maximum with 0.8 per cent carbon when exposed to the action of dilute sulphuric acid. Clearly there is some difference of behavior towards all the corroding media in the case of the steels in the neighborhood of the eutectic composition, the specimens showing either a tendency toward increased corrosion or else a most decided increase in corrosion.

The addition of 0.7 per cent manganese to the above steels first results in a very slightly increased corrosion in tap-water, sea-water, and in wet and dry tests, with a carbon content up to about 0.4 to 0.5 per cent. From this point upwards the manganese, generally speaking, affords a slight protection, which is very decided in the wet and dry tests, but is not invariable in the sea-water tests.

A second result of the addition of 0.7 per cent manganese to the above steels is an enormously increased corrosion in dilute sulphuric acid. This is particularly important, since in commercial steels the manganese content frequently ranges from 0.2 to 0.7 per cent, and it is evident that the latter are absolutely unsuited for exposure to acidified corroding media. Just as in the experiments with the steels of 0.2 per cent manganese content, a point of maximum corrosion is observed; but this always occurs with a smaller carbon content in the steels with 0.7 per cent manganese.

By increasing the manganese content to 2 per cent upwards—(*a*) The corrodibility in neutral solutions is greatly decreased, particularly when the carbon content exceeds 0.5 per cent. (*b*) The corrodibility in dilute sulphuric acid is greatly enhanced.

The authors emphasize the fact that they have confined themselves exclusively to a consideration of the actual results obtained with the steels without in any way considering the theoretical reasons for the observed phenomena.

### Copper and Lead

**Decomposition and Reduction of Lead Sulphate.**—A contribution to our knowledge of the behavior of lead sulphate at elevated temperatures is offered by W. MOSTOWITSCH, of Tomak, Russia, in the May *Bulletin* of the American Institute of Mining Engineers. In studying the decomposition of lead sulphate by heat, the author found that partial dissociation, with evolution of $SO_3$, begins at 800 deg. C.; that the speed of dissolution is slow up to 950 deg. and quick when the temperature is raised above 950 deg.; that fusion, which occurs between 950 deg. and 1000 deg., takes place only after partial decomposition of normal $PbSO_4$. Up to 1000 deg. C. no volatilization of PbO was observed, but above that temperature it was very noticeable, forming a sublimate on the boat.

In the presence of silica the dissociation temperature of $PbSO_4$ is not lowered. It is marked at 950 deg. and increases as the temperature is raised. The decomposing effect of silica is not proportional with the $SiO_2$ content, but rather the reverse holds true. Decomposition appears to be governed by the viscosity of the lead silicate which is formed; in the bi- and trisilicate mixtures viscuous slag envelopes $PbSO_4$ and retards action. The most rapid decomposition accompanied by the lowest loss of lead by volatilization is found with a silication lying between the singulo- and the bisilicate and containing from 10 to 15 per cent $SiO_2$.

The reduction of $PbSO_4$ by CO begins at 600 deg. C.; the salt loses in weight and becomes dark; $SO_2$ is set free. At 630 deg. C. there are visible pellets of lead, and the loss in weight of 21.58 per cent exceeds the oxygen content, which is 21.11 per cent. All the phenomena prove that a reaction between undecomposed $PbSO_4$ and reduced PbS is taking place according to the two equations: $PbSO_4 + PbS = 2Pb + 2SO_2$ and $3PbSO_4 + PbS = 4PbO + 4SO_2$.

With carbon the reduction, which begins at 550 deg. C., is accompanied by the liberation of $SO_2$. At 630 deg. the reduction proceeds more quickly than at 550 deg., the loss in weight is larger, and pellets of metallic lead are seen; the $PbSO_4$ has been largely changed to PbS. At 700 deg. the reduction to PbS and Pb is completed.

A comparison of the effects of the two reducing agents shows that CO begins to act at 600 deg. C,. and carbon at 550 deg.; that the reducing power is increased with the temperature when CO acts more powerfully within the given limits than carbon does, for example, at 630 deg. the CO reduced 74.4 per cent and C only 36.98 per cent of the $PbSO_4$.

In applying the foregoing results to reduction in the blast furnace, we have to consider the reducing agents and the temperatures. In the blast furnace the reducing agents are the solid carbon of the coke and the gaseous CO of the ascending gas current which travels at a rate of about 22 ft. per second. The furnace charge receives from 12 to 15 per cent coke. The gases passing from the throat of the furnace at a temperature of from 100 deg. to 150 deg. C. contain $CO_2$ 15 to 21, CO 5.4 to 11.0, and oxygen 0.4 to 1.0 per cent by volume; usually the ratio of $CO_2$ : CO is as 3 : 1. The reduction of $PbSO_4$ by carbon and CO is energetic at 600 deg. C., and with it takes place the action of $PbSO_4$ upon PbS; both reactions occur at a temperature below that of decomposition of $PbSO_4$ by heat alone. The elimination of sulphur which may amount to from 25 to 40 per cent is therefore largely due to the action of $PbSO_4$ upon PbS in the upper part of the furnace. An advantage in using blast-roasted lead ore as regards elimination of sulphur lies in the fact that the sulphur is present mainly as sulphate which is readily eliminated as $SO_2$ and does not increase the matte-fall. The CaO of the limestone added to the blast-roasting charge ($CaCO_3$ = per cent S + 2 per cent) is converted into $CaSO_4$, and this is either reduced at 800 deg. C. to CaS and enters the slag as sulphide, or it is dissociated at 1000 deg. C. by $SiO_2$ and enters the slag as silicate. The $SO_2$ of $CaSO_4$ in blast-roasted ore has therefore as little influence upon the matte-fall as has the $SO_2$ of $PbSO_4$. Slags running high in FeO have been found to hold in solution as much as 7 per cent S; thus two slags made at Stolberg, Rhenish Prussia, with 55 and 38 per cent FeO contained 7.4 and 3.7 per cent S.

**The flowing temperature of copper and copper-nickel mattes** has been investigated by G. A. GUESS and F. E. LATHE to determine whether copper-nickel mattes might have a lower flowing temperature than copper mattes, and thus aid in accounting for the difficulty thus far experienced in pyritically smelting copper-nickel ores. The results are offered to the American Institute of Mining Engineers for presentation at the Arizona meeting this fall. Both laboratory and commercial mattes were investigated, the former being formed by fusing mixtures of white metal from copper converters and copper-nickel converters with varying amounts of iron sulphide.

The results of the experiments did not show as great a difference in flowing temperature between copper and copper-nickel mattes as was expected. The latter appear to have a flowing temperature from 30 to 50 deg. below copper mattes of the grade usually in blast-fur-

nace work. This slight difference in temperature is not regarded as sufficient to explain the failure in pyritic smelting due to a too early liquation of copper-nickel matte in the furnace. The paper gives tables and curves showing the differences in temperature observed for both copper and copper-nickel mattes prepared in the laboratory and secured from operating furnaces.

## Recent Chemical and Metallurgical Patents

### Gasoline

**Gasoline and Other Volatile Hydrocarbons from Petroleum Residues.**—A patent issued to CHARLES S. PALMER of Upper Montclair, N. J., on a process of treating petroleum residues to obtain volatile products, has for its essential feature the use of considerable pressure. The original application was filed on March 2, 1907.

The process consists in treating material such as "Florence," "Boulder," "Wyoming," "California," or "Louisiana" pitches or residues which are non-volatile below 300 deg. C. The residues are first melted in a steam-jacketed kettle, then delivered to a digester in which they are heated. During this treatment which occupies only a few minutes, the pressure gradually increases with the temperature, until a pressure of about 130 lb. per sq. in. is reached. There is then a sudden conversion of the materials present into more volatile compounds, which causes a rapid increase in the pressure without any substantial temperature increase. Apparently endothermic reactions take place which use up the heat as it is supplied.

The digester is connected to a still by a pipe line in which is a check valve which allows vapors to pass over above a certain pressure. The vapors from the digester are collected in the still and distilled separately from the undecomposed residues remaining in the digester. The fractional distillation of the collected volatile products yielded fractions as follows in actual tests: Up to 100 deg. C., about 5 per cent; 100 to 150 deg. C., 10 to 20 per cent; 150 to 200 deg. C., 10 to 20 per cent; 200 to 250 deg. C., 20 to 30 per cent; 250 to 300 deg. C., 10 per cent.

As illustrative of the effect of pressure it is stated that at 200 to 325 deg. C. and 60 to 90 lbs. pressure only 25 to 35 per cent of volatile products are obtained. With the same temperature limits and 100 to 150 lb. pressure, 50 to 75 per cent volatile products are obtained. At pressures ranging from 150 lb. up to 300 or 400 lb., 75 to 90 per cent volatile products are obtained. The first claim of the patent is as follows: "The process of treating petroleum residues of the parafin series to increase the yield of volatile compounds above that normally obtainable therefrom, which consists in digesting the same in a confined space under a pressure in excess of four atmospheres and not exceeding 400 lb. per sq. in., said pressure being principally autogenous, and at a temperature in excess of 200 deg. C., for a time sufficiently long to induce transformation of the major portion of said materials treated into more volatile products, said temperature being below that point at which sufficient corbonization occurs to substantially interfere with such transformation, and said digesting being conducted with the treated materials being continually subjected to the pressure throughout the said digesting period of the evolved volatilized compounds undiluted bv added aqueous vapors." (1,187,380, June 13, 1916.)

### Electrolytic Processes

**Process of Making Formic Acid.**—A process of making formates and formic acid by the action of an alkali amalgam on an aqueous solution saturated with carbonic acid gas, is patented by MOOSHEGH VAYGOUNY, of Berkeley, Cal., and assigned to the Royal Baking Powder Co. The process can be readily understood by references to the illustration, Fig. 1. A is a suitable container of non-conducting material, having on the bottom a layer of mercury B. Another vessel C, open at both ends, dips into the mercury B. An

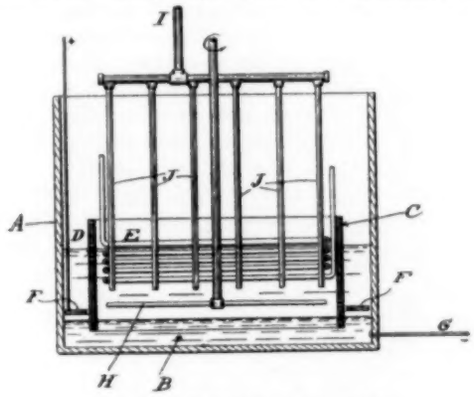


FIG. 1—FORMIC ACID CELL

anode F of platinum, and a cathode G, connected with the mercury, are provided. A strong solution of potassium hydroxide is placed in the space D, and water is placed in the inside space E. Carbonic acid is introduced into the water in E by pipes J, and the solution is stirred by stirrer H.

As a direct current is passed from F to B, an amalgam will form in the mercury. By diffusion, assisted mechanically by stirrer H, or by rocking the cell, this amalgam is caused to travel to chamber E. Here reactions take place which form bicarbonate and formate. Potassium hydrate and hydrogen are first formed, the hydrate then combining with the carbonic acid to form bicarbonate and the hydrogen reducing the carboxyl grouping to the formate grouping. The temperature is kept below 40 deg. C., and the solution is allowed to become concentrated enough in formate so that the bicarbonate will be practically insoluble, thus effecting a separation of these two. The formate solution may be evaporated and crystallized and the formate worked up into formic acid. (1,185,028, May 30, 1916.)

**Electrolytic Preparation of Tartaric Acids.**—An electrolytic process of making tartaric acids from gly-

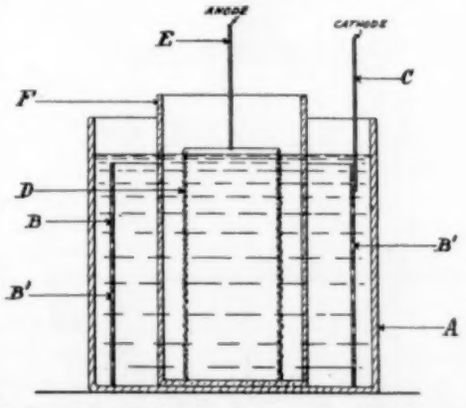


FIG. 2—ELECTROLYTIC CELL FOR TARTARIC ACID

oxylic acid or glyoxalates is patented by MOOSHEGH VAYGOUNY, of Berkeley, Cal., and assigned to the Royal Baking Powder Company. The process is carried out in a cell made of wood or other non-conducting mate-

rial. In Fig. 2, A represents the container, B the copper cathode with perforations B', D the platinum gauze anodes, and F a diaphragm. The material used as the diaphragm is not mentioned.

Into the cathode space of the cell is placed a solution made up as follows: 500 c.c. contain 32 gr. potassium glyoxalate, 20 gr. potassium sulphate, and 0.5 gr. potassium hydroxide. For this quantity of solution the cathode surface should be about 200 sq. cm. About 60 cc. of 5 per cent sulphuric acid is introduced into the anode chamber. The cathode solution is agitated and electrolytic reduction is carried on with a current density of about 1 to 4 amp. per sq. dcm. The temperature is kept at about 25 deg. C, and should not exceed 40 deg. C. In about 2½ hr. reduction is complete. The potassium sulphate is added to increase conductivity and prevent glyoxylic ions from being carried into the anode compartment. The solution should be neutral or slightly alkaline.

After electrolysis, the solution consisting of potassium sulphate, potassium tartrates, and small amounts of oxylate and glycolate, is treated with calcium sulphate to precipitate the tartrates. The solution is filtered and the tratrates (racemic and meso) are separated by well known methods. (1,181,555, May 2, 1916.)

**Separator for Electrolytic Oxygen Cell.**—A separator of rubber-covered metal designed to be used in an electrolytic oxygen and hydrogen cell such as described in patents No. 1,172,886 and 1,172,887 (reviewed in our issue of March 15, 1916, page 342), is the subject of a patent of HENRY R. SWARTLEY, Jr., of Manhasset, N. Y. (assigned to Davis-Bournonville Company of Jersey City, N. J.). In the cell described in the above-mentioned patents the anodes are surrounded by trough-shaped separators, from which are suspended asbestos sacks which serve as the diaphragm. The separators should be capable of withstanding caustic solution and oxygen, and should be non-conducting. The present patent states some of the objections to various materials. Glass, while not entirely unsuitable, is subject to attack by the caustic electrolyte, and is fragile. High quality, vitreous porcelain presents manufacturing difficulties, and is also fragile. Hard rubber does not have sufficient rigidity. The separator with a core of metal and a covering of hard rubber is stated to produce a practical and efficient separator. The core may be drawn in a press to the desired shape, the rubber is applied in a plastic condition and then vulcanized. (1,176,105, March 21, 1916.)

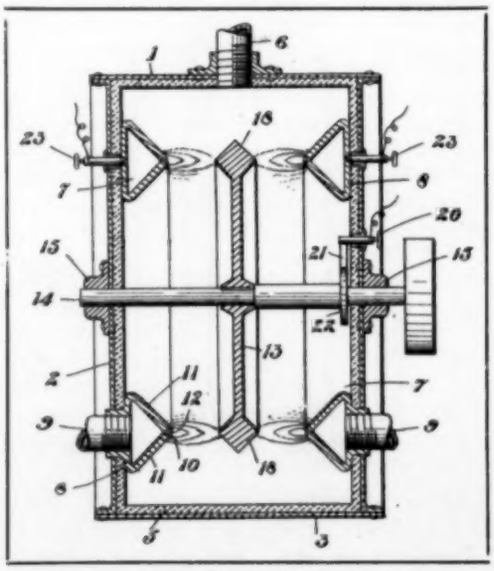


FIG. 3—INSIDE VIEW OF FURNACE

### Nitrogen from Air

**Electric Nitrogen Fixation Furnace.**—A novel method of forming the arc in an atmospheric nitrogen fixation furnace is described in a patent of JAMES S. ISLAND of Toronto, Ont., Canada. Two sectional views of the furnace are shown in Figs. 3 and 4. Fig. 3 is a longitudinal vertical section and Fig. 4 an end vertical section. The outer casing 1 has a silica lining and is shaped as shown; 7 represents tubular ring-shaped members, triangular in shape, as shown, and having perforations 11 in them to allow of a distribution of the air which comes in through pipes 9. The rotating

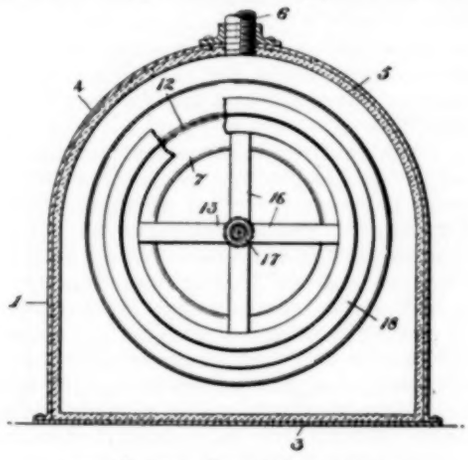


FIG. 4—END VIEW OF FURNACE

element 13 has four radial arms holding diamond-shaped sections 18. Binding posts 23 are connected to two or more terminals of a source of polyphase current and a brush at 22 connects with the rotating element and binding post 20. The arc forms when the current is on and the arc is an annular one, due to its being drawn out by the rotating element. (1,179,927, April 18, 1916.)

### Miscellaneous

**Extraction of Radium From Carnotite.**—A process of recovering radium from carnotite ores or concentrates by treatment with sulphuric acid is the basis of a patent granted to HERMAN SCHLUNDT of Columbia, Mo. The inventor has found that a selective extraction of radium can be made by concentrated sulphuric acid, and that the radium sulphate and accompanying barium sulphate, which are soluble in the hot concentrated acid, can be separated practically completely by mere dilution with water. The ore is ground to 20-mesh and boiled with sulphuric acid at about 60 deg. Baume, until a temperature of 230 deg. C. is reached. The acid liquor is then separated from the ore while still hot; the residue is washed with concentrated acid, and from the clear acid liquor thus obtained the radium is recovered by diluting with water. In practice the quantity of water is from five to ten times the volume of acid. After removing the concentrated acid from the residue the latter is washed with water, yielding a blue liquor containing vanadium and uranium compounds. The latter also are found in the dilute acid liquor from which radium sulphate has been precipitated, and by concentrating these liquors, uranium and vanadium compounds tend to crystallize out, while the concentrated acid can be used for treating further ore. (1,181,411, May 2.)

**Production of Phosphorus in the Blast Furnace.**—A process of producing phosphorus and its compounds, together with phosphoric alloys of the metals, by smelting natural phosphates with metallic ores and fluxes in a blast furnace, is outlined by JOHN J. GRAY, JR., of Rockdale, Tenn., in a patent recently granted him. Tri-

calcium phosphate, silica, coke or charcoal, lime or other basic material, and ores of iron, copper, nickel, etc., are smelted in proper proportions in a blast furnace. Part of the phosphorus passes out of the furnace with the other gases and is recovered as red phosphorus, orthophosphoric acid or in any other desired form. The balance of the phosphorus is combined with the metal derived from the ore being smelted, and is recovered as an alloy of such metal. The process results in a high recovery of phosphorus, due to the maintenance of a molten bath of metal and slag in the furnace, which facilitates the escape of $P_2O_5$ vapors. The inventor claims that his process obviates the difficulties formerly encountered in attempting to recover phosphorus by blast-furnace treatment. (1,168,495, Jan. 18, 1916.)

### Metallurgical Furnaces

**Roasting Furnace.**—A method of constructing superposed desulphurizing furnaces, patented by HARRY H. STOUT of New York City and assigned to the General Chemical Co., has for its object the regulation of heat distribution and control of temperature on each of the several hearths of the furnace. This is accomplished by a system of flues and conduits, whereby air is caused to extract heat from zones of high temperature and transfer it to zones of low temperature. (1,181,183, May 2, 1916.)

**Agglomeration of Sulphides for Pyritic Smelting.**—JAMES H. PAYNE of Baltimore, Md., has patented a process of agglomerating sulphide ores or concentrates, with the retention of substantially all the sulphur contained in the original material. For this purpose the ore is heated to incipient fusion in a rotating kiln in a reducing or neutral atmosphere. On discharging from the kiln the material flows into molds and is cooled by water sprays without opportunity for oxidation. The product is specially adapted to blast-furnace smelting where sulphur is utilized as fuel. (1,181,244, May 2, 1916.)

**Recovery of Sulphur in Roasting Sulphide Ores.**—A furnace particularly adapted to the roasting of sulphide ores and the recovery of the sulphur is patented by HOWARD F. WIERUM of Upper Montclair, N. J. The

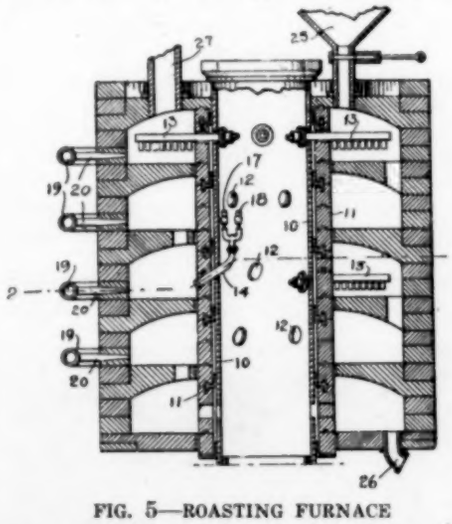


FIG. 5—ROASTING FURNACE

furnace, illustrated in Fig. 5, is of the superimposed-hearth type, and the particular improvements consist in means for introducing steam into the hearths through tangential openings and applying fuel flames to the ore by burners placed on the inner revolving shaft of the furnace, at a point slightly in advance of the rabble arms or immediately following them.

In the illustration, 10 represents the inner hollow shaft, and 12 indicates openings for rabbles. A burner is shown at 14, being placed slightly in advance of the rabble arm on that hearth. On the outside of the furnace is a bustle pipe 19 through which steam is delivered to tangential inlets 20. It is claimed that this arrangement of burners and steam pipes offers advantages over that arrangement where burners are on the exterior wall of the furnace and steam inlets are directed diametrically across the hearths. (1,162,894, Dec. 7, 1915.)

**Treatment of Ore and Recovery of Sulphur.**—A furnace in which several operations are conducted consecutively is patented by UTLEY WEDGE of Ardmore, Pa. It consists of superimposed hearths constructed in muffle form, the furnace being divided into three zones of three hearths each. In the upper zone it is designed to eliminate the sulphur from the ore, and to maintain such an atmosphere, by the introduction of steam, that the metal will be converted to the oxide and the sulphur eliminated without oxidation. In the second zone the oxidized metal is subjected to the action of reducing gases, whereby the oxide ore becomes "metallized." The lowest zone of three hearths is intended as a gas producer where carbonaceous matter is burned or distilled, the gases being conducted to the upper and intermediate zones of the furnace as needed.

In the upper zone the oxygen for oxidizing the metal is provided by the decomposition of steam. Atmospheres of 4 or even 6 per cent of oxygen will oxidize metal with inconsiderable oxidation of sulphur, and carbon dioxide will do the same at the necessary temperature. The practical range of temperature for the vaporization of sulphur and the oxidation of metal in the case of iron sulphide is from 1400 deg. to 1600 deg. Fahr.

Conducting the operations as a continuous process effects economy in fuel. The ideal condition would be to generate a strongly reducing gas in the lower zone for delivery at a high temperature to the intermediate zone where the oxidized metal is to be "metallized." After the gas had performed its function in the intermediate zone and having lost to some extent its reducing character, it could be conducted to the upper zone. (1,169,444, Jan. 25, 1915.)

**Combined Sintering and Smelting Apparatus.**—In several patents granted to ARTHUR S. DWIGHT of New York City apparatus is shown for the combined and continuous treatment of ore by first sintering into a rigid cake and then smelting in a reverberatory furnace. The sintering apparatus is of the type commonly known as the Dwight-Lloyd, consisting of a series of grate-bottomed pallets receiving a charge of ore to be sintered, and successively carrying the charge under an igniting mechanism and over a chamber from which air is being exhausted, with the result that the sulphurous material burns and causes the entire mass to agglomerate into a porous, rigid cake. In the present invention this cake is continuously discharged into a smelting furnace, whereby the heat of the sinter is economized in the smelting operation. The smelting furnace is of the reverberatory type, with fuel-oil or other burners so disposed that their flame will impinge on the entering sinter and fluxes and cause them to separate into matte or metal and slag in the usual manner. (1,169,069-139-384, Jan. 18 and 25, 1916.)

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**Industrial Preparedness.**—The June issue of the *Journal* of the American Society of Mechanical Engineers contains a full account of the exceedingly interesting discussion on "organizing for industrial preparedness" at the New Orleans meeting of that society, April 11 to 14, 1916.

## Novel Construction of Storage Buildings

The Griffin Construction Company, Atlanta, Ga., is erecting two cotton-seed storage buildings for the Buckeye Cotton Oil Company's Atlanta mill. The type of construction used is novel and also new for this purpose.

By using a type of tile in which there is a U-shaped groove for holding reinforcing rods the boiler plate originally specified was done away with. In this way it has been possible to reduce the construction cost to as low a figure as $3.50 per ton of material stored. The buildings are absolutely fireproof, being built of concrete and fireproof tile reinforced with steel. The roof of the buildings will be of steel.

The two buildings are each 75 ft. in diameter and 60 ft. high, having a total capacity of 7000 tons. The floor is of concrete and the foundation extends about 3 ft. below the surface, resting on heavy clay. Fig. 1 is an outside view of the two storage buildings, while Fig. 2 shows clearly the special construction of the tile. Corrugated steel bars placed in the "U"-groove are held in place with concrete. Wet, heavy cinders are placed in the tile under the rods to keep the concrete around the rods. In the first 25 ft. of tile two ½-in. bars were placed in the grooves, in the next 25 ft. of tile ⅝-in. bars are used and in the top 10 ft. of the structure ½-in. bars. The bottom 10 ft. have two thicknesses of tile while above that point one thickness is used.

The cotton seed is put into the buildings from the top at the center, thus making a cone-shaped pile tending to push down on the sides of the walls instead of sideways. The danger of the walls bulging out is thereby decreased. An "A"-frame steel tunnel runs through the center on the bottom of each building in which a conveyor will be placed which will be used to remove the seed.

Not only is the cost of the structures reduced to the low figure of about $3.50 per ton of material stored, but by this type of building the insurance rate is cut down to practically nothing.

FIG. 1—TILE FOR STORAGE BUILDING CONSTRUCTION

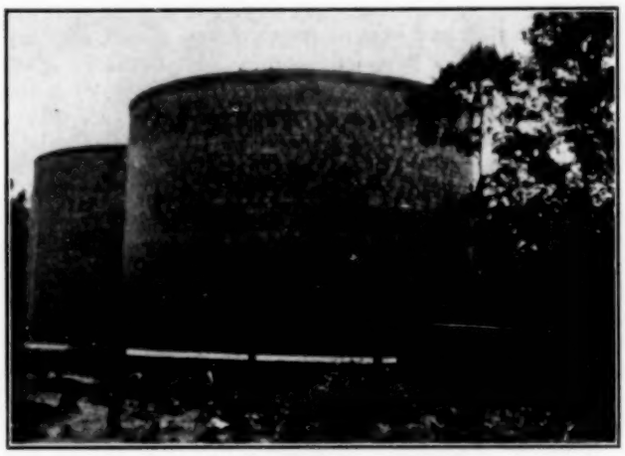


FIG. 2—STORAGE BUILDINGS

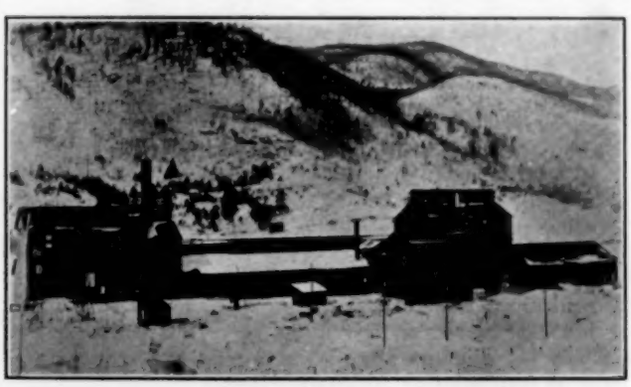
Eight storage buildings of almost similar construction are being built for Swift & Company's mill at Augusta, Ga. W. M. Griffin is the designer.

## A Modern Hydrated Lime Plant

The Vermont Marble Company of Proctor, Vt., have just put into operation one of the finest rotary kiln and hydrated lime manufacturing plants in existence. This plant is located at West Rutland, Vt., and was built for the purpose of utilizing waste products from the various operations of the company, their purpose being to turn this waste into valuable chemical, hydrated and agricultural lime products.

The waste material being brought in from the quarries and factories is discharged directly to a No. 6 crusher, unless the lumps are so large that an earlier preparation is required, in which case the material is elevated and put into the large 60-in. x 48-in. Superior jaw crusher. This crusher reduces the stone to 6 in. and under, and the discharge from the crusher is arranged to flow directly into the No. 6 gyratory crusher. Leaving the No. 6 crusher, the limestone is lifted and discharged directly into a rotary screen which eliminates the fines, allowing the coarser material to pass to a 36-in. x 18-in. roll crusher, which reduces to the same fineness as the screen product, both streams flowing directly to a common elevator discharging onto a belt conveyor. At this point the very fines are screened out and conveyed over to the Pulverized Agricultural Limestone Department. The coarser material is discharged to a large circular storage tank, for night operation or for making the operation continuous, and also to the large storage bin above the rotary kiln.

The kiln department has been made sufficiently large so that a second complete unit can be installed, each



HYDRATED LIME PLANT OF VERMONT MARBLE COMPANY

unit consisting of one 8-ft. x 125-ft. rotary kiln with the storage bins and one 5-ft. x 50-ft. rotary cooler. The storage bin above the kiln is arranged with a cradle type of feeder operated from the kiln-driving mechanism, so that the flow of the material is under control at all times.

The kiln is fired by producer gas which is generated in a separate building and led over to the kiln by means of a gas flue. The discharge from the rotary kiln flows by gravity directly to the 5-ft. x 50-ft. rotary cooler. The burned lime discharging from the cooler flows directly to an elevator discharging into the two large oxide bins, through screens which eliminate any coarse or foreign unburnt material.

One of these oxide bins is arranged to feed directly into an elevator discharging to a "Kritzer" six cylinder hydrating machine. The other oxide bin is so arranged that its contents can also be conveyed to the "Kritzer" hydrator, but this bin was installed primarily for the purpose of loading the lime in oxide form directly into cars for shipment.

The hydrating equipment consists of the following:

1—No. 4 six-cylinder Kritzer hydrator.
2—Air-separating and dust-collecting outfits.
2—Beater mills.

Following this equipment there is installed a large compartment bin arranged for packing the various qualities of lime products in a "Bates" four-tube lime packing machine located below, a dust collector system is also installed in connection with this packer.

The stock house is arranged for the storage of the hydrated lime packed in bags. This building has a capacity of from 1500 to 2000 tons.

In the gas producer house the fuel for burning is brought in and discharged directly into a hopper below the track and is then carried by means of a belt conveyor to a crusher discharging directly to an elevator discharging to a belt conveyor leading to the bin above the gas producer or discharging directly to the covered coal storage. This storage has a capacity of from 250 to 300 tons. The gas producer is of the "Chapman" mechanical type, and this producer installation is modern in every particular.

In general, the buildings are of steel frame construction covered with corrugated iron siding and roofing. The various machines throughout the plant are amply proportioned for the various operations and each machine is driven by individual motors.

The power for operating the plant is received from the hydro-electric stations owned by the Vermont Marble Company.

The whole plant is laid out for future extensions.

There is also a department for pulverizing lime for agricultural purposes. This equipment consists of one 33-in. Fuller Lehigh pulverizer with its accessories. An additional stock house and shipping facilities are arranged in connection with this department.

This plant has a capacity of 75 tons of hydrated lime daily and 50 tons of agricultural lime, and in addition to the above, arrangements have been made so that crushed stone for fluxing or other purposes can be shipped.

The large crusher has a capacity of some 240 tons per hour which is sufficient for all later extensions, but this crusher was installed originally for the purpose of reducing large lumps which otherwise could not be handled satisfactorily.

This plant is the most modern rotary-kiln hydrated lime plant in existence. It was designed and constructed by the Fuller Engineering Company of Allentown, Pa.

## Large Single Cylinder Engines for Rolling Mills

A single-cylinder engine which has many points of interest and which is finding use in rolling mills, due to its capacity for extreme overloads is the so-called "uniflow" engine. This engine owes its efficiency to the reduction of the loss by initial condensation. The exhaust is at the center of the cylinder, and the engine is, therefore, suitable to wide temperature ranges. Expansion from boiler pressure down to condenser pressure may be carried out in one cylinder with steam economy equivalent to a tandem compound engine. Tests have shown that 200 per cent load can be carried with only 10 per cent increase in steam consumption.

Uniflow engines have been installed for rolling mills in Germany, one of the largest engines on record having a maximum continuous capacity of 6300 hp. and a short duration peak load capacity of 8000 hp. The average load is 4000 hp. This engine is a 67 in. by 55½ in. at 120 r.p.m., installed at the Röchlingschen Steel & Iron Works at Völkingen, built by Erhardt & Sehmer, operating with steam at about 130 lb. pressure and 525 deg. Fahr., total temperature (169 deg. superheat) and drives a 30-in. three high mill. A second engine of the same make has a capacity of 1600 to 2400 hp. and is 43 in. by 51 in. at 120 r.p.m., being installed at the Rombacher Iron & Steel Works.

In this country the first uniflow engines for rolling mill work are those now under construction by the Nordberg Manufacturing Company, Milwaukee, Wisconsin, for the Youngstown Sheet & Tube Company, Youngstown, Ohio, the larger to drive a 12-in. rod mill, the smaller a 9-in. rod mill. The general design of the cylinders is shown by the longitudinal section of Fig. 1. The cylinder is a plain cylindrical casting, all valve chambers and steam passages being contained in the heads, bolted to the ends of the cylinder. This prevents distortion and strains due to expansion and contraction with the use of high pressures and superheats. The steam valves are of the poppet type, the valve cages being separate castings which are ground into the heads with a steam tight joint. The valves are of the double beat, balanced poppet type and no packing is required for the valve stems, which are accurately ground and polished and work in ground and lapped bushings. The valves are operated from lay shaft by a releasing valve gear with spring dashpots, the cut-off being under control of the governor through the wide range of loads. The steam enters the cylinder at the bottom, sweeping up over the heads and jacketing them before entering the valve at the top. The exhaust is through the ports

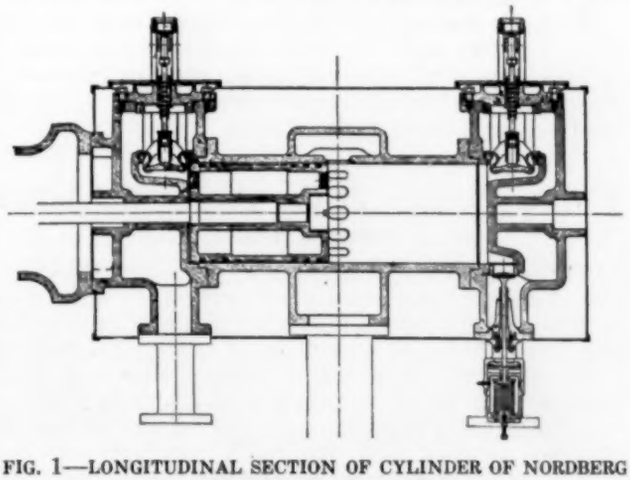


FIG. 1—LONGITUDINAL SECTION OF CYLINDER OF NORDBERG POPPET UNIFLOW ENGINE

in the center of the cylinder uncovered by the piston near the end of its stroke. Relief valves of the poppet type with cataract dampening device are located near the bottom of the heads. In case of loss of vacuum and over-compression these valves automatically open and connect the clearance space of the cylinder with the steam space in the head and the communicating steam piping. The steam conditions will be approximately 170 lb. pressure, 75 deg. superheat, and 20 in. vacuum, steam being condensed by barometric jet condensers.

The larger engine is 44 in. by 50 in., 110 r.p.m. and will have a capacity from 700 hp. to between 3000 and 4000 hp. The weight, including 110,000 lb., 10 ft. flywheel, will be 480,000 lb.

The second engine is a 37 in. by 48 in. at 110 r.p.m. and its weight, including a 90,000 lb. flywheel, will be 360,000 lb.

## Alunite in British Columbia

Deposits of alunite have recently been discovered on Vancouver Island in British Columbia, according to Commerce Reports. The analysis of the alunite-bearing rock shows a lower potash content than the high-grade deposits in Utah. Following are analyses of three samples taken from different places in the deposit.

| Vancouver Alunite. | No. 1 | No. 2 | No. 3 |
|---|---|---|---|
| Silica | 52.00 | 55.65 | 44.40 |
| Alumina | 19.95 | 16.30 | 21.80 |
| Sulphuric acid | 16.00 | 15.10 | 21.40 |
| Oxide of iron | 2.05 | 2.15 | .70 |
| Potash | 5.60 | 4.30 | 4.50 |
| Water, etc. | 4.40 | 6.50 | 7.20 |
| Total | 100.00 | 100.00 | 100.00 |

The results of the above analyses might be compared with three typical analyses of the alunite from Marysville, Utah:

| Utah alunite | 18 | 19 | Dana |
|---|---|---|---|
| Alumina ($Al_2O_3$) | 37.18 | 34.40 | 37.0 |
| Ferric oxide ($Fe_2O_3$) | Trace | Trace | .... |
| Sulphuric trioxide ($SO_3$) | 38.34 | 36.54 | 38.6 |
| Phosphorus pentoxide ($P_2O_5$) | .58 | .50 | .... |
| Potassium oxide ($K_2O$) | 10.46 | 9.71 | 11.4 |
| Sodium oxide ($Na_2O$) | .33 | .56 | .... |
| Water ($H_2O$ plus) | 12.90 | 13.08 | 13.0 |
| Water ($H_2O$ minus) | .09 | .11 | .... |
| Silica ($SiO_2$) | .22 | 5.28 | .... |
| | 100.10 | 100.18 | 100.00 |

There is a possibility that more extended investigations of these deposits may bring to light a higher grade of rock. This possibility is shown by the fact that a small sunken island some little distance from the mainland contains rock of a much higher potash content than any of the samples above enumerated from Vancouver, all of which were collected at a short distance from the coast and on the hillsides.

Raw alunite has already been largely used directly as a fertilizer with manifest advantage. The roasted mineral, however, gave double the yield in increasing the crops when experimental comparisons were carried out on similar tracts of land.

## Moving Pictures at the Second Exhibition of Chemical Industries

The many favorable comments received on the showing of the motion picture films at the 1915 Exposition of Chemical Industries, led the management of the coming Second National Exposition of Chemical Industries to be held at the Grand Central Palace, New York City, week of Sept. 25, to arrange a motion picture program broader in scope than that prepared for the former exposition.

Many films have been secured during the past six months from large industrial corporations throughout the country through the Bureau of Commercial Economics at Washington. These motion picture films will be shown daily during the Exposition and will be of special interest to every visitor.

Among the films already arranged, are the following showing:

The Match Industry.
The Rubber Industry.
Manufacture of Explosives.
Varnish Manufacture.
Silver Mining.
Mining and Manufacturing of Iron.
Making of Blotting Paper.
Accident and Fire Prevention.
Manufacture and Use of Fertilizers.
Manufacture of Steel.

The motion picture program will include films of such industries that are dependent upon chemistry.

Arrangements have also been made to exhibit the motion picture film taken of the members of the American Chemical Society in Danville during their Spring meeting in April.

The managers report they have at this time twice the number of exhibitors they had last year at the Exposition, and much new apparatus and processes will be exhibited for the first time at the coming Exposition. In no other exposition of any kind can the technical or business man find so much of vital interest and real immediate benefit to repay him for a visit.

## Personal

Mr. **G. M. Bissel** has become associated with the steel-car sales department of Kilbourne Jacobs Mfg. Co., Columbus, Ohio.

Mr. **J. A. Burgess** has resigned as superintendent of the Wonder Nevada Mining Co., to become general superintendent of the United Eastern Mining Co., Oatman, Ariz.

Dr. **Frank K. Cameron,** formerly in charge of the fertilizer investigations of the U. S. Bureau of Soils and chemical engineer with the Utah Potash Co., a company operating on the property of the Florence Mining & Milling Co., Marysvale, Utah, is now in Washington, D. C., where he has taken up consulting work with special reference to fertilizer problems.

Prof. **Joseph Daniels,** assistant professor of Mining and Metallurgy, University of Washington, at Seattle, Wash., departed from the university as soon as the college year closed, recently for Thane, Alaska, to engage in practical study of mining through work in the Alaska-Gastineau mill, where he will have the opportunity to observe and study the processes of breaking, rolling and concentrating as applied to low-grade gold ore. Mr. Daniels will be away from the University until the middle of September.

Mr. **Ralph L. Fuller,** vice-president of Harshaw, Fuller & Goodwin, manufacturers of chemicals, was elected president of the Cleveland Chamber of Commerce at its recent annual meeting.

Mr. E. R. **Grasselli,** second-vice-president and treasurer of the Grasselli Chemical Co., is vice-president of the chamber.

Mr. **H. A. Guess** has been appointed managing director of the mining department of the American Smelting & Refining Co.

Mr. **C. F. Harrington,** mechanical engineer formerly with the New York Central Railroad, is now sales engineer with the Powdered Coal Department of the Bonnot Co., Canton, Ohio.

**Mr. Maxim L. Kagan,** general manager of Franz Krull, Ltd., Reval, Russia, who is here on Government business, has just placed an order with H. L. Barnitz, sales agent of the International Oxygen Co. for a large oxyhydrogen plant of the unit-type generators; the gases produced by this plant to be used for welding and piped throughout their works. Mr. Kagan recently placed orders on refrigerating machinery for the Russian Government aggregating over half a million dollars.

**Mr. G. S. Kelley,** formerly with the Digger Machinery Co., Inc., has recently been appointed sales representative of the John F. Allen Co. of New York, in connection with the new department they have established for the manufacture of coal-handling and hoisting machinery.

**Mr. Isaac H. Levin** announces that he has resigned as chief engineer and chemist of the International Oxygen Co. in order to devote his time to chemical research and as a specialist in the electrolytic field. His temporary address is 186 Hillside Ave., Newark, N. J.

**Mr. Arthur D. Little,** of Boston, Mass., is at present, together with Mr. George Bury, vice-president of the Canadian Pacific Railway, on a trip of inspection through Canada to Vancouver. As was formerly noticed in this journal, Mr. Little and his firm have been retained by Lord Shaughnessy, president of the Canadian Pacific Railway, to assist in carrying out extended plans for a scientific research of Canada's natural resources. Mr. Little's present trip is for the purpose of making a preliminary investigation of the situation and laying out the plans for the future work of his staff.

**Mr. H. W. Sparks,** sales manager of the Kalbfleisch Corporation, Chattanooga, Tenn., was in New York a short time ago at the office of the Franklin H. Kalbfleisch Co.

## Industrial Notes

**The Norton Co.,** Worcester, Mass., has issued a new catalogue describing its grinding wheels and machinery. It is beautifully illustrated and contains much information on alundum and crystolon besides the various products made from them.

**Microscopes and Accessories.**—The Bausch & Lomb Optical Co., Rochester, N. Y., has issued a new catalog describing Bausch & Lomb microscopes and accessories. This is the twenty-fourth edition, the first having appeared in 1874. The present catalogue offers the most complete line yet presented. Of especial interest is the new complete series of apochromatic objectives, the first to be offered by an American manufacturer.

**Portland Filter.**—The Colorado Iron Works Company, Denver, Col., has issued pamphlet No. 28-B, describing the Portland Filter. The description is very complete and includes all the details of construction, together with a list of users of this filter.

**Electroplaters Convention.**—The 1916 meeting of the American Electroplaters Society will be held in Cleveland, Ohio, from July 6 to 8. It is the intention to spend less time on business meetings and more time on papers and discussions than at previous meetings.

**A. H. Ney, Inc.,** announces that they will continue the business of consulting chemists and chemical engineers, heretofore conducted under the name of A. H. Ney, Ph.D. The new company has been organized to provide increased facilities for its clients in consulting and chemical engineering work, in connection with the installation of plants for the organic chemical industry. The chief lines embraced will be dyes and intermediates, high explosives, medicinal chemicals and photographic developers.

**The Vulcan Soot Cleaner Co.,** of Du Bois, Pa., state that their New York representatives, the De Ved-Kissick Co., 149 Broadway, New York City, have recently obtained a large order for the type of apparatus manufactured by that company. Vulcan soot cleaners are to be installed on fifty boilers of the B & W type, totaling 30,000 hp. rated capacity, at the Marion plant of the Public Service Electric Co. of New Jersey. In this plant the boilers are set singly with dusting and blow doors on each side, through which a hand steam lance was inserted for hand blowing, these being favorable conditions for soot cleaning by hand as compared to plants where the boilers are set in batteries and have to be cleaned entirely from one side. It was considered more economical, however, to equip the plant with Vulcan soot cleaners. With mechanical soot cleaners the boiler tubes can be kept clean and more efficient in absorbing heat with much less cost for labor.

**Common Sense of Export Trade.**—In an address before the Executive Club of Chicago, on May 26, Stanley H. Rose, at that time commercial agent of the Bureau of Foreign and Domestic Commerce, but now with the Barber Asphalt Paving Co., discussed some of the important points connected with building up of our export trade. One of the chief difficulties which he mentioned was the lack of young men trained in foreign languages and in export trade and having first-hand experience in foreign countries. Another difficulty is the shortage of American ships. Our export trade is increasing gradually, but we could sell ten times more or perhaps a hundred times more, if we realized the importance of going after the business as soon as possible.

**Paul O. Abbé,** 30 Broad Street, New York City, has issued Catalogue "B," which includes descriptions of disintegrators, caged mills, crushers, the improved rotary cutter and other apparatus. Considerable space is devoted to the rotary cutter, which is used in a great variety of industries, in the reduction of various materials.

**Cellulose in Wood.**—The Forest Products Laboratory, Madison, Wis., has perfected a method of determining the chemical constituents of wood. From tests made it has been found that the production of cellulose in modern pulp-making is from 5 to 20 per cent less than the amount in the wood.

**The Yaryan Rosin & Turpentine Co.** will build a $250,000 wood pulp plant at Brunswick, Ga. This plant will be operated in connection with the company's distilling plant and will produce Kraft pulp. It is also claimed that a cheap gasoline can be produced from the company's products.

**Increased Production of Manganese Ore.**—The production of manganese ore in 1915 was 9651 long tons, the largest since 1901 and more than three times the 1914 production, according to the Geological Survey. The imports were 313,985 tons showing the comparative insignificance of our domestic production. Eighty-five per cent of the imports came from Brazil, and about 36,450 tons came from India. None was received from Russia. The production in the United States of manganiferous iron and silver ores was 798,404 tons, which was almost twice the 1914 output. This was mostly used in making high-manganese pig iron, but some was used as a flux by lead smelters and some to make low-grade ferromanganese.

**Factory Notes** is the title of a monthly pamphlet published by the United States Cartridge Co. of Lowell, Mass. The first number appeared in February, 1916. The Welfare Association of the company has evidently a great deal to do with the issue of this paper. Among its councilors is Mr. H. B. Coho, the widely known former secretary of the New York Section of the American Electrochemical Society. According to the June issue of Factory Notes the latest undertaking of Mr. Coho is the formation of a United States Cartridge semi-military company or battalion.

**The Improved Equipment Company,** New York City, has entered into an agreement with Waldo Brothers, Inc., Boston, Mass., whereby the latter will act as agents in the New England States for coal gas plants, and accessory apparatus designed by the Improved Equipment Company.

**Cooling and Cleaning Air for Generators.**—The Carrier Air Conditioning Company, Buffalo, N. Y., has issued Bulletin No. 253 describing Carrier cooling and cleaning systems for generator and transformer ventilation. The booklet gives a description of the Carrier air washer and explains the increased power obtained by cooling and washing the air which is used in ventilating a generator.

**Association of Chemical Manufacturers formed in Great Britain.**—At a meeting of chemical manufacturers held in London on May 23, it was decided to form an Association of Chemical Manufacturers, in order to aid in the building up of the chemical industries in that country, and to help them meet foreign competition after the war. A committee was appointed to prepare plans for the new association.

**Poidometers.**—The Schaffer Engineering & Equipment Co., Tiffin, Ohio, has issued Bulletin No. 5, describing the Schaffer poidometer with liquid measure attachment for automatic weighing of miscellaneous materials. The liquid measure attachment is a device which delivers a predetermined number of pints per minute in proportion to a predetermined number of pounds of solids on the poidometer, giving a mixture of any desired consistency.

**Peat Powder for Railroad Use.**—A report has been made concerning the use of peat powder by the Swedish State Railways, according to Commerce Reports. This report discloses the fact that the administration of these railroads has requested the King to propose a bill in the present Riksdag for an appropriation for the erection of a peat-powder factory for their use. The report is as follows:

> The investigation concerning the possibility of using peat powder for the locomotives of the State railways has now been finished and the railway directors have placed the results before the King. They have also requested the King to propose a bill in the present Riksdag for an appropriation of 1,300,000 crowns ($348,400) for the erection of a peat-powder factory at the Hästhagen bogs and for the use of enough locomotives for peat powder so that all the trains on the Falköping-Nässjö line may use this fuel.
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> After a careful examination the railway directors state that they have found peat powder to be very efficient and practical for locomotives, with a fuel value, compared with that of coal, of about 2 to 3. The ratio of peat powder will probably be greater when it has been used and experimented with further. Therefore it is considered a good thing to use peat powder, especially as the country's own resources will be utilized.
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> In order not to have to depend on private industry and the fluctuations of the market, the directors thought it would be advisable for the railways to have a peat-powder factory of their own, and estimates of the cost of erecting a factory have been given. The Hästhagen bogs have been chosen as a suitable place, as it is estimated that 20,000 tons of peat powder can be produced there annually for twenty years. This amount is required by the Falköping-Nässjö line for that period.
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> Using the ratio given and calculating from the lowest estimate for its production, the cost of peat powder, per ton, would be 15 crowns ($4.02) and the corresponding price of coal would be 22.50 crowns ($6.03) per ton. When calculating the price at 15 crowns per ton the items included are: Cost of running the factory, interest on the cost of changing locomotives for the use of peat powder, patent cost, and royalty. The company that erects the factory will charge 25,000 crowns for the use of the patent and 50 ore ($0.134) per ton of peat powder as royalty.
>
> The 1,300,000 crowns asked for would include the cost of buying the bog and sufficient solid ground, the erection of the factory, patent cost, cost of tracks to the bog, and cost of changing the locomotives.

## Book Reviews

**Materials of Construction.** By **G. B. Upton.** Octavo (14 x 23 cm.), 327 pages, 181 illustrations; price, $2.50 net (10/6 net). New York: John Wiley & Sons, Inc.; London: Chapman & Hall, Ltd.

This book covers the structure and properties of the more common materials, being an outgrowth of a laboratory course given by Professor Upton to junior students at Cornell University.

Part I deals with the experimental determination of properties, such as the common mechanical tests, aging, corrosion, rusting, etc. This part is elementary, the discussion being largely based on the internal condition of the material during the test.

Part II discusses the internal properties of materials by metallographic study, and their control by mechanical and heat treatment. It would appear as if this should have preceded Part I, because the phenomena thus determined are made the basis of the analytical treatment of the substance of Part I.

Aside from this, the discussions of Part II, which is really a short study in theoretical and applied metallography, are entirely beyond the field of the usual engineering student; its explanations being in hypotheses of physical chemistry which are doubtful or even dubious, its theories are somewhat overloaded in bearing the weight of the phenomena which they are called on to explain.

**Mechanical Technology.** By **G. F. Charnock.** Octavo (13 x 21 cm.), 635 pages, 503 illustrations; price, $3, net. New York: D. Van Nostrand Company.

The sub-title indicates the field covered as the materials and preparatory processes of the mechanical industries. One-fourth of the contents cover the production and properties of the metals and alloys, another fourth their molding and casting, another various mechanical operations involving their change of shape by forging, stamping, rolling, drawing, spinning, pressing, etc., and there are some minor chapters on timber, stone, abrasives, lubricants, rubber, leather, rope, etc.

The part treating of production and properties is necessarily a brief summary of a very large subject, of very little use to a metallurgist and of little real value to a civil, electrical or mechanical engineer; the foundry section is better; the section on mechanical working is a good summary for metallurgists and chemists, in fact, for them the most valuable part of the book, because of its condensed character.

The metallurgical part is poorly written and its chemistry is weak; the book would be much more useful and reliable if its first 160 pages on production and properties were condensed into, say, 50 pages on properties alone, leaving the student to find production of metals and alloys in books or treatises written by competent metallurgists. The mechanical practice described is mostly English, and does not correspond in many cases to best American practice.